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REPORT ON THE MAPS AND SURVEYS

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BRITISH (TERRA NOVA) ANTARCTIC EXPEDITION
1910—1913

REPORT

ON THE

MAPS AND SURVEYS

BY

F. DEBENHAM, O.B.E., B.A., B.Sc. (SYDNEY), M.A. (CANTAB.),
Fellow of Gonville and Caius College, Geologist on the Expedition

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II. Ross Barrier, Northern Edge. (Inset Cape Crozier.)
III. Ross Island to the Pole.
IV. The McMurdo Sound Region.
V. West Coast of Ross Island. (Inset Erebus Summit.)
VI. Granite Harbour Region.
VII. Ferrar-Koettlitz Region.
VIII. Cape Evans and Inaccessible Island.
IX. Cape Royds District.
X. Hut Point Peninsula.
XI. Glacier Tongue, Ross Island. (Erebus Bay Ice-Tongue.)
XII. Mackay Ice-Tongue, Granite Harbour.
XIII. Robertson Bay.
XIV. Terra Nova Bay.

FOREWORD.

THE form in which this Report is now finally published differs considerably from that of the original plan, and the author feels that the reasons for the modifications should be explained.

The Honorary Editor of the Physical Reports of the Expedition, Colonel H. G. Lyons, F.R.S., had originally planned a memoir which was to contain a critical discussion of the more precise work, to be written by himself, as well as full reports by the various officers concerned with the survey work.

The cartographical part of the work was put into the hands of Lieutenant H. de P. Rennick, R.N., who had acted as First Officer of the *Terra Nova* for most of her cruises, and he was assisted by other naval members of the expedition, especially by Lieutenant H. L. Pennell, R.N., who had been in charge of the ship in all her survey work.

Rennick did a vast amount of preliminary work, and by July, 1914, all the primary positions had been reduced and drawings had been made of some of the maps. On the outbreak of war this work had to be set aside. A few months later Rennick was drowned while rescuing survivors of the torpedoed H.M.S. *Hogue*, and two years later Pennell, as navigating commander of H.M.S. *Queen Mary*, was lost with the rest of the ship's company at the battle of Jutland. When the end of the war came, therefore, the two men who were most concerned with the hydrographic work and who had completed much of the framework of the maps were no longer available.

In 1919, Colonel Lyons handed over the material to me to proceed with as best I could. It should be explained that on the expedition I was a geologist and not directly concerned with survey operations. As a result of a good deal of experience with survey parties in Australia, however, I was naturally interested and gladly assisted when called upon, so that the general procedure, instruments, etc., were quite familiar to me.

For the regrettable delay in the completion of the work some apology is required. It has been done in the intervals from other duties and proved to be a great deal more laborious than was expected. Owing to loss of papers and the change in plans much of Rennick's careful work had to be done over again, and all except three of the maps had to be drawn. It would hardly be ready now were it not for help from numerous sources.

Notes on methods and experiences were always readily forthcoming from other members of the expedition, Evans, Campbell, Priestley and Wright being often called upon. Wright in particular was able to give excellent advice as he took a leading part in many of the operations himself. Where possible the men responsible for the actual observations are mentioned by name in the text, both as a reference and as a tribute. To all these my thanks are due, but in still greater measure is it due to the Editor, whose long experience with work of this nature enabled him to settle problems easily which were quite beyond my powers, and whose patience at the delays was inexhaustible.

The author trusts that in spite of its many shortcomings this report may be of practical value to future expeditions and may serve as a foundation for very great improvements to come.

F. DEBENHAM,
Gonville and Caius College, Cambridge.
August, 1923.

CHAPTER I.

INTRODUCTION.

The surveying which was carried out by the British Antarctic Expedition of 1910–13 included work of so many kinds and covered so wide an area that a short account of its scope is desirable before proceeding to deal with the particular surveys.

The expedition was divided into two landing parties, the main body, having its headquarters at Cape Evans, on the west side of Ross Island, and an auxiliary party which was landed at Cape Adare and is referred to as the Northern Party in this memoir. The general supervision of the survey work was in the hands of Lieutenant (now Captain) E. R. G. R. Evans, R.N., who did the greater part of the work on land during the first year, but he was assisted by many other members of the expedition who often undertook separate parts of the work. These will be mentioned as their work is discussed. Surveying being only one of very many activities of the expedition there was no definite organisation of parties or of methods for that purpose, and a great deal of the work was left to the general duty of members to make observations whenever possible.

The result was, as is common in polar exploration, a vast amount of material which was gathered on no preconceived plan but rather as opportunity arose, and this somewhat unwieldy mass has had to be carefully examined before the final maps could be made.

The work may be conveniently treated under three general headings, which are distinct by reason of the different methods used. Of these, the work at the main base is the most important, involving as it did the careful determination of the geographical co-ordinates, and an attempt at a triangulation of the immediate neighbourhood; naturally, the work was done with instruments and by methods not suitable for extended survey in the field. Under the second heading comes the general topographic work of the various sledging parties, work which was carried out under all the inconveniences of rapid travel in polar conditions and which cannot aim at a very high order of precision. Finally, when the ship had landed the various parties she made several running surveys and carried out a large programme of hydrographical work under the direction of the late Lieutenant H. L. Pennell, R.N.

The whole of this work is here collected and discussed, but before passing on to the plan of treatment it will be as well to outline the work of previous expeditions in this region of the Antarctic so far as the fixing of positions is concerned. Special reference to them will be made when a comparison is possible between the various determinations, but, unfortunately, there is no detailed record of the survey work done by them except in casual references in the pages of their narratives, and what may be inferred from a study of their charts.

The pioneer of discovery in this region, Captain Sir James Clark Ross, is responsible for the earliest survey, and his determinations are of great importance. In his two visits to the sea now bearing his name, he surveyed the coast of the mainland from Cape Adare down to the northern end of McMurdo Sound in such detail as was possible from sailing ships. With even greater care a survey was made of the face of the Great Ross Barrier as far as " an appearance of land " which later proved to be part of Edward VII Land. There is scant reference to the methods used in these surveys, but we may presume they were made with all the accuracy that was possible at the time, the bulk of the work being done by the senior officers of the two ships and the charts prepared by a skilled draughtsman, Mr. J. E. Davis, second master of the *Terror*.

Many of the determinations of position made by the expedition are published in the leader's narrative,* which is the source of those referred to in this memoir.

In 1899–1900 an expedition under Mr. Carstens Borchgrevink spent a winter at Cape Adare and afterwards cruised in Ross Sea, approximately in Ross's track. Fresh determinations of some of the main points by Captain Colbeck are available for general comparison.†

In the period 1901–04, the National Antarctic Expedition under Captain Scott carried out a series of land surveys in the neighbourhood of Ross Island. The position of the winter quarters on the south-west point of the island was carefully determined, and based on that was a series of sledge journey traverses, including one to Lat. 82° 16′ S., Long. 164° E., over the surface of the Barrier and another to Lat. 78° S., Long. 146° 33′ E., over the surface of the continental plateau, besides many smaller journeys of equal importance from a topographical point of view.

Equally useful were the surveys made by the ship before and after her detention in the ice, consisting of a running survey of the whole coast of South Victoria Land from Cape Adare to Ross Island and along the face of the Barrier to the newly discovered Edward VII Land. On the way home a more accurate determination of the position of the Balleny group of islands was made. The cartographer of the expedition was Lieutenant G. F. A. Mulock, R.N.‡

The work of this expedition covered a great deal of ground and, since it has formed the basis of later work, it is of great importance to verify and discuss their determinations. This will be done where possible, but, unfortunately, much of the data is no longer available except in abbreviated form.

In 1907–09, the British Antarctic Expedition under Sir Ernest Shackleton visited the same region and made two long traverses, one to within 100 miles of the Pole and another along the coast of Victoria Land and inland to the region of the Magnetic Pole. In this expedition the first use of the plane-table in these regions was made, a survey of the surroundings of the winter quarters at Cape Royds on the west coast of Ross Island being made with a bulky type of table. No detailed work was attempted but the traverses, which were made by astronomical fixes and sledgemeter distances. are of considerable value, and that done by the Western Party under Professor (now Sir) T. W. E. David and carried out by Mr. (now Sir) Douglas Mawson, corrected a great many inaccuracies in the coast line due to the difficulties of making a satisfactory coastal survey from a ship.

---

* " A Voyage to the Southern Seas."

† " First on the Antarctic Continent," C. Borchgrevink, is the official narrative of this expedition and gives some account of the survey work, an account which is quite spoilt by egregious typographical errors.

‡ A few pages of description, written by Mulock, of the cartographical work of the expedition was published with the maps.

When the 1910 (Terra Nova) Expedition arrived the survey of the region therefore consisted of one good determination of geographical co-ordinates for the station of the Discovery Expedition (Hut Point), and a series of traverses based on it and checked by occasional astronomical determinations. In many of these, however, the positions of points were taken as a basis without careful verification, and the general result of some of the route surveys is therefore untrustworthy.

The maps of the expeditions are, therefore, compilations of data of very varying accuracy, and as such are open to criticism.

The determinations of position of this expedition will be compared as far as possible with those obtained by the former expeditions in order to arrive at the most probable positions of well-defined points. In some cases this will be possible, but in most the results of previous expeditions have not been published in sufficiently detailed a form to allow of a critical examination being made.

The instruments which were used will first be described with the criticisms of them furnished by those who used them. Next, the observations for the determination of the geographical position of the winter quarters will be summarised and the results compared with those of the previous base stations. Then follows a description and discussion of the various surveys with an account of each map.

CHAPTER II.

THE SURVEYING INSTRUMENTS.

The question of the most suitable types of instruments for work of this kind is an exceedingly important one, so it is proposed to describe somewhat fully the equipment and its performance under the unusual conditions of polar survey.

THEODOLITES.

Most of the recent expeditions have decided in favour of theodolites instead of sextants for land work, and the performance of the 3-inch instruments taken by Captain Scott on the *Discovery* left him in no doubt on the matter. Accordingly the most important instruments were the six theodolites specially made for the expedition, by Messrs. T. Cooke and Sons, of York and London (*see* Plate 1).

They were 4-inch transit theodolites, and especial care was taken to make them as compact and light as possible, while all the parts that required manipulation were made easily accessible to gloved hands. It may be noted here that for the best work with a theodolite gloves cannot be used, and for all ordinary summer work it became the practice to adopt loose fingerless gloves or " mitts " which could be slipped off for the few moments necessary for light adjustment of the screws. In the winter this was only possible when it was perfectly calm, and gloves had to be used to the detriment of the accuracy of adjustment.

Both horizontal and vertical circles were 4 inches in diameter at the reading edge ; they were divided on silver to 30 minutes and were read by two verniers on each circle to 30 seconds. Small microscope readers were provided, having a quick thread for convenience in focussing and as a safeguard against loss ; the readers were hinged so that they could be folded back when not in use, thus reducing the size of the box.

The telescope was designed with special care in order to produce one of the maximum power for the size of the object glass allowed. It had a clear aperture of 1 inch with a focal length of 6·5 inches. Low and high power eyepieces of the inverting type, giving powers of 15 and 25, were provided, and were fitted with a screw focussing arrangement similar to that of the vernier readers. The telescope was constructed to transit with the object glass end down, the focussing tube racking out at the eyepiece end. A special fitting was supplied, carrying a revolving disc in which coloured shade glasses of different densities were mounted, together with a blank aperture, and this could be slipped on to either of the eyepieces.

The diaphragm was of glass, ruled with one horizontal and three vertical lines, which for summer work and sledging was probably the best. For work in low temperatures on the other hand, when all surfaces were liable to have rime condensed on

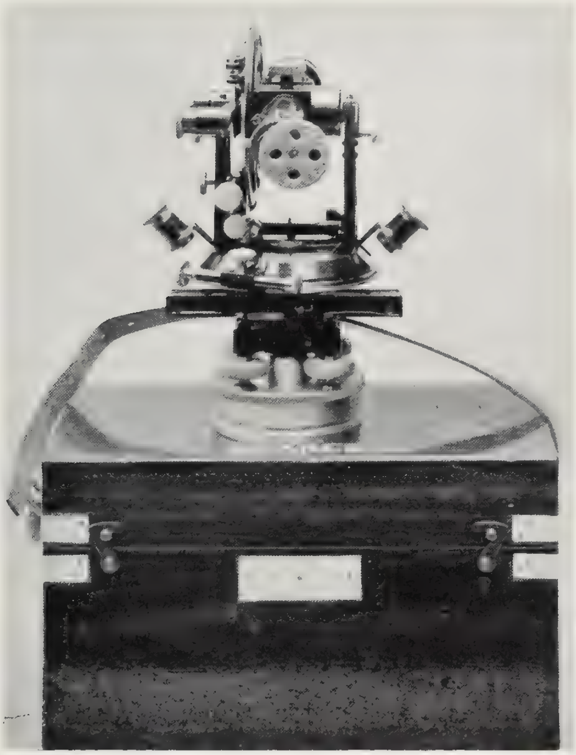

Plate 1.--The 4-inch Cooke Theodolite used on the Expedition, shown on its box mounting.

To face p. 4, Report on Maps and Surveys.

them, the glass of the diaphragm sometimes became so clouded as to prevent observations. For this reason it would have been convenient to have had a spare diaphragm with spider lines for work at headquarters in the winter.

A levelling arrangement of four foot-screws was selected by the surveyors of the expedition as giving more stability to a light instrument, but experience showed that any gain in this respect was probably outweighed by the troublesome necessity of having to use two hands for levelling as well as the difficulty of estimating by touch with cold hands when the screws were bearing properly. The foot-screws, as well as all the other screw-heads and the eyepieces, were covered with chamois leather for convenience in handling at low temperatures, and these proved very satisfactory.

The standards were made as short as possible, the trunnions of the transit axis fitting into round shaped bearings. Over these were brass caps which could be easily removed if necessary to reverse the axis.

A light trough compass, reading to degrees with a 4-inch needle, was provided. The sliding weight on this was not sufficiently heavy to counteract the excessive dip and had to be increased with copper wire which was liable to shift.

A very important addition to the bubbles of the spirit levels was made in the form of chambers to every one, so that the size of the bubble could be regulated for any extremes of temperature. The contraction of the spirit in an unchambered level increases the size of the bubble so much that it cannot be read at low temperatures, and since the crossing of the tropics had also to be provided for, it could not be arranged simply to have a very small bubble at ordinary temperatures. The long plate bubble was divided to 0·05 inch, each division being equivalent to 30 seconds of arc, whilst the divisions of the short plate bubble were equal to one minute. The azimuth bubble was mounted on the vernier arm of the vertical circle and had divisions of 0·05 inch, each of which was equivalent to 20 seconds of arc, and the divisions numbered.

The instrument case was made of mahogany $\frac{3}{8}$-inch thick, with the lid tongued so as to prevent wind-driven snow from getting inside it. The outside dimensions were $11\frac{3}{4}$ inches by $6\frac{1}{2}$ inches by 7 inches, all corners being aluminium bound, and a light leather carrying strap was provided. The theodolite packed into its case in one piece, that is, the body and the telescope were not taken apart for packing purposes, an important consideration both from the point of view of saving space and convenience in setting up.

In each box were a number of accessories, consisting of two screw-drivers, two levers, a camel-hair dusting brush, a reflector to fit the object glass end for star work, a dark head for solar use, and a supply of instrument oil in a metal bottle. No plumb-bob was provided or required ; in the few cases when accurate centring of the instrument was necessary, it was done with a temporary weight.

In addition to the above, a small glass diaphragm ready mounted in its brass cell, complete with four collimating screws and packed in a small aluminium box, as well as a set of three spare bubbles, was supplied for every second instrument. The particular cases in which these extra parts were packed were marked " Spares."

The packing of the instrument in its case was very successful, no case of injury from faulty replacement being recorded, and at the same time it was simple to take out and replace.

Each instrument was provided with a spare aluminium ring carrying the same thread as that on the tripod head. This ring was provided with three bayonet-joint holes, so that it could be attached to the top of the box instead of to the tripod if required. It thus formed a stand which could be bedded on a snow-pillar and take the place of the tripod if it were broken or missing.

The tripod was 3 feet 8 inches long with legs of ash which folded up to a round form but were cored out inside for lightness. A large diameter screw on the tripod head engaged with the corresponding aluminium socket or base on the theodolite. No centring movement was provided.

Folding aluminium knees were fitted to the base of the legs to prevent them sinking too far into the snow; they were about 4 inches long and might have been increased. Occasionally on the soft snow of the Barrier the legs had to be pressed down over a foot to get reasonable stability.

The instruments were constructed throughout of special gun-metal with the exception of the base which was of aluminium. The weights were as follows :—

	lbs.
Instrument*	6
Box with accessories	4
Tripod	4

The general performances of this instrument will be detailed later, but it may be remarked here that for sledging work it was excellent in every way and gave complete satisfaction. It was so light that it could be taken on long walks on foot or up steep ascents without difficulty, it was sufficiently strong to withstand the capsizes and other mishaps inseparable from sledge transport, and it was easily manipulated in low temperatures. The tripod was small enough to pack easily on the sledge but was a model of firmness; sights were taken by the observer resting one knee on the ground; this was found to be a little troublesome as the position had to be shifted for reading the circles, but the saving in weight was worth that trouble for journeys of any length. It would have been convenient to have had one or two tripods of the normal length fitted with plumb-bob and centring head for use near headquarters.

It must be admitted that for the more precise work of triangulation the instrument was not of the most suitable type nor was it designed for such work; indeed, the need of a theodolite capable of work of the standard of topographical triangulation was much felt. Expeditions intending to carry out anything more than route traverses are strongly advised to take a 5-inch micrometer theodolite; preferably one which can be packed in one box, with the spare parts in a second one if necessary. It must be recognised that surveying in the neighbourhood of headquarters is of an altogether different character to that of sledging journeys, and the conditions of weight and portability do not preclude the use of precise instruments.

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* This instrument is still listed in the catalogues of the maker.

For purely astronomical work at the base two telescopes were available, both of which were lent to the expedition by Colonel J. W. Gifford, of Oaklands, Chard, who calculated the optical data for them.

The first was an achromatic telescope of $3\frac{1}{4}$ inches aperture and 24·375 inches focus. The object glass of this telescope was a doublet of borosilicate crown and ordinary dense flint glasses, and was corrected as regards colour and spherical error for rays near the margin. This instrument was also provided with a Zeiss orthoscopic eyepiece of 6 mm. focus for star work.

The second was an apochromatic telescope of $1\frac{1}{2}$ inches aperture and $11\frac{1}{4}$ inches focus. The object glass of this was a cemented triple of baryta light flint, borosilicate flint, and borosilicate crown glasses.

Both telescopes were provided with specially constructed high power achromatic erecting eyepieces with magnifying powers for the two telescopes of 120 and 56 respectively. The larger instrument, which was used for observing occultations, was mounted for use on a portable tripod stand with an equatorial mounting of the ordinary type by Messrs. Baker, of Holborn. For the smaller instrument an ordinary light wooden folding camera stand with a simple rotary head was taken. The equatorial mounting gave no trouble and caused no unsteadiness.

CHRONOMETERS.

The *Terra Nova* carried eight chronometers, namely :—

Maker.	Number.	Reference Letter.	Where Employed.
Kullberg	6617	A	Ship.
Kullberg	5338	B	Ship.
Uhrig	451	C	Cape Adare (Lieutenant Campbell).
Keys	954	D	Ship.
Kullberg	7653	E	Cape Evans.
Uhrig	482	F	Cape Evans.
Bruce	1218	G	Cape Adare (Lieutenant Campbell).
Webb	5447	H	Cape Evans.

These were all kept in chronometer boxes of the old service pattern, of which the base was made of well-seasoned wood, two layers of rubber being laid upon this, on which the chronometers rested. The compartment of each box was well padded with horsehair and the whole was surrounded by the usual protecting cover.

At Simonstown, about August 22, 1910, on the journey out, the india-rubber sheet on the back of the chronometer box pedestal was increased to twice its ordinary thickness as the chronometer room did not prove quite so free from damp as had been anticipated, although it was the dryest place in the ship. On the passage from New Zealand to McMurdo Sound the minimum thermometer in the chronometer room was found to be giving inaccurate readings owing to the index of the thermometer moving with the ship's rolling. The temperatures at the time of reading were therefore recorded, the indications of the minimum index being ignored.

The chronometer room was in the hold below the wardroom pantry and was situated immediately abaft the engine room; the heat from this kept the room dry, but rather large variations of temperature occurred between the days when steaming and those when only a small fire was kept up in one furnace to prevent the water from freezing in the boilers.

When the Main Party had been landed at Cape Evans, three of these chronometers were taken on shore for use there, and two at Cape Adare, the remaining three being taken back by the ship to New Zealand for the determination of the longitude of the base at Cape Evans.

On shore at Cape Evans the chronometers were kept on a shelf about three feet from the floor in the North-east corner of the hut, close to the cubicles of Lieutenant Evans and Dr. Wilson. A maximum and minimum thermometer hung on the wall a short distance away and on the same level, and this was read every morning when the comparisons of chronometers and chronometer watches were made.

Chronometer E was taken as the standard chronometer on shore throughout, and the comparisons of the other chronometers and watches with it were made at about 8 a.m. daily.

Immediately after the comparison all the chronometers and watches were wound. The method of comparison was that chronometer F was first compared with E, then H with E, and then the watches were compared with E in turn. The comparisons were made with E when it marked the 30th or 60th second, and the time shown by the other time-keeper was recorded to the nearest half-second. During the second year the watches were only compared occasionally, but the chronometers were compared every morning as before. As the observatory clock was then in the next cubicle comparisons of E, F and H with it were made later in the day, using the method of coincidences. For this purpose the beats of the clock were made audible to the observer who was making the comparisons by using the pendulum coincidence apparatus. This was kept in the vicinity of the chronometer shelf and never re-adjusted. The temperature was read and recorded after these comparisons had been made.

The chronometer watches were used on the sledge journeys and were carried in a small wash-leather pocket sewn on to the inner vest just above the belt line. At first they were wound daily, but on account of accidents in letting watches run down it became the practice later to wind watches twice a day, before and after the march. As will be related later, no full account of their performance on the main journey can be given.*

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* With the advent of W/T signals the carriage of time has begun to lose its terrors, but it is doubtful whether watch-chronometers for sledging parties can be superseded for a long time to come.

SLEDGEMETERS.

Six sledgemeters were taken for the purpose of determining the distance traversed by parties for the calculation of dead reckoning. These were constructed by Messrs. S. Smith and Son, of Great Portland Street, London, and comprised a trailing wheel which was lined on its periphery with an aluminium band fitted with small pegs ; these latter were provided in order to obtain a grip on harder surfaces while at the same time the aluminium prevented the snow from clinging to the wheel. The wheel itself was mounted in a fork to which was attached the mechanism for registering the mileage. This was driven by gearing which was completely enclosed and on the dial of the counter was recorded the distance travelled in geographical miles (2,028 yards), while subdivisions showed hundreds of yards. An additional hand was also fitted to record trip runs up to 50 miles, which could be set at any time without interfering with the record of the total mileage. The fork was fitted to a three-foot bar of hickory which at the other end was attached to a cross bar by a leather joint, which allowed a good deal of twist in the sledge without throwing the wheel out of the perpendicular. These sledgemeters came in for a good deal of criticism from the members who used them, and certain of the defects might be avoided in future. Thus, on hard surfaces, the wheel would run on the small spikes instead of the real perimeter and introduce an error which would make the distance recorded too small. This could be prevented to some extent by reducing the size of the spikes to little more than slight roughness. The wheel itself runs so easily that a rasped surface should be sufficient to prevent it slipping. When the snow is really soft, which does occasionally happen in the summer, the snow will clog on the wheel no matter what the surface is made of, and even grease or blubber smeared on the wheel has but little effect then.

The counter-mechanism of the instrument was made by Kelvin and James White, of Glasgow, and gave satisfaction in general. The real defect in the construction of the sledgemeter was the connecting bar of hickory being too weak and the universal joint not working properly. It must be remembered that even over the snow plain of the Barrier capsizes of the sledge are to be reckoned with, and on the glaciers they are very frequent. The connecting bar is wrenched each time that this takes place and requires to be of considerable strength. The question of a universal joint is also a difficult one for if it is made too stiff the whole wheel throws up in the air when the sledge capsizes, and if too easy the wheel will fall over on its side while running. The question of a design of sledgemeter needs further attention.

Of the six that were taken only two survived and nearly all gave trouble at one time or another.

ANEROIDS.

Twelve aneroids were supplied by Messrs. T. Cooke and Sons, and were all 3 inches in diameter They were carefully constructed and special care was taken with the compensation in preparation for the unusual conditions which they were to meet. The backs of the cases were made to revolve carrying the whole movement with them, including the needle, and by this means the whole of the instrument, with the exception of the dial, could be turned round until the needle marked the desired reading, thus avoiding any interference with the movement itself. The adjustment was clamped by a screw at the side. The numbers and altitude scales were as follows :—

Numbers 760, 761 and 762 had altitude scales up to 12,000 feet.
,, 756, 757, 758 and 759 ,, ,, 8,000 ,,
,, 755, 754, 753, 752 and 751 ,, ,, 6,000 ,,

The cases of these aneroids were made of aluminium and each was packed in a double bag of canvas stuffed with horsehair.

Each instrument before delivery was tested over the range of pressure corresponding to the altitude scales with which they were engraved.

MINOR INSTRUMENTS.

Amongst the minor instruments forming part of the equipment were hypsometers. These were of the ordinary pattern, and the thermometers had the National Physical Laboratory's certificate of corrections. They were needed especially for the plateau part of the journey to the Pole, but, unfortunately, the thermometers were all broken on the upper part of the Beardmore Glacier. They were also used on the ascent of Mount Erebus.

Hundred-foot steel bands were included in the stores but were not used except for the checking of sledgemeters. Their neglect was not, however, due to their inapplicability to survey work there, and it should be noted that over fast sea-ice the desiderata of level surface and firm support for pegs are amply fulfilled, so that the use of steel tapes for base lines, especially if the ends of the base are on land, is recommended.

The high degree of visibility, which is so characteristic of the climate, suggested the use of tacheometric methods for linear measurement. Some preliminary work with the 4-inch theodolite used as a tacheometer was carried out by C. S. Wright with excellent results, but this was undertaken towards the end of the second year and only partial use was made of them.

A bowl compass with needle floating in spirit was used to some extent for giving the course when sledging. It gave fair results when deposited on the snow, but it could not be used with accuracy when held in the hand. A lighter and handier design of spirit compass was much needed. The ordinary prismatic compass proved to be of no value for taking bearings anywhere in the vicinity of McMurdo Sound on account of the proximity of the Pole, consecutive readings often differing by as much as five degrees.

A plane table was constructed and gave good results ; a description of the instrument used is given in the last chapter.

Lieutenant Evans made considerable use of a small sextant in "walking in" the coastline for the local surveys, and each naval officer had his own sextant. They were never used on sledge journeys but at headquarters they were used with an artificial horizon (mercury) for time and azimuth observations.

For purposes of navigation on the Pole journeys, a very useful little home-made instrument in the form of a portable sundial was used. This was constructed out of the three-ply Venesta wood of which all the food cases were made, in the form of a disc with a short handle. One side of the disc had a circle of bearings in quadrants of 90° marked on it and within that a circle of hours, two sets of 12 hours. Through the centre a small hole was bored to take a stout needle threaded on a small lanyard, the needle when not in use being inserted in a hole for it bored parallel to the surface of the disc.

It is clear that such a dial could be used at or near the Pole for determining time from the sun if the meridian is known or, conversely, to find the meridian if the time is known. For latitudes other than 90° however the pin should, of course, be inclined and the graduations would not be evenly spaced, the modifications depending upon both the latitude and the sun's declination, the errors being greatest for minimum latitude and maximum declination.

For latitudes between 78° S. and 90° S., and for declinations from 8° S. and 23° S. the graduations would be fairly evenly spaced. For summer journeys to the Pole and back the agreement is quite good, since the latitude is low when the sun is low. The following table shows the approximate azimuths for various hour angles, the dates, latitudes and declinations being those corresponding roughly to the movements of the Pole Party in 1911 and 1912.

Hour Angles.	November 3, 1911. Lat. 78° S. Decl.	December 1, 1911. Lat. 83° S. Decl.	January 1, 1912. Lat. 85° S. Decl.	February 1, 1912. Lat. 83° S. Decl.	February 29, 1912. Lat. 80° S. Decl.	Lat. 90° S.
	°	°	°	°	°	°
1	16·2	15·9	15·7	15·7	15·5	15·0
2	32·3	31·7	31·1	31·4	31·2	30·0
3	48·2	47·2	46·7	47·0	46·3	45·0
4	63·5	62·6	62·0	62·1	61·7	60·0
5	78·5	77·7	77·2	77·3	76·3	75·0
6	86·8	87·3	87·9	87·8	88·6	90·0
7	72·3	72·4	73·0	73·1	73·6	75·0
8	57·8	58·0	58·3	58·5	59·4	60·0
9	43·5	43·7	43·7	43·9	44·3	45·0
10	29·1	28·9	29·0	29·1	29·7	30·0
11	14·5	14·4	14·5	14·6	14·9	15·0

The azimuth is counted from North or South whichever is the nearest. The table has been prepared by C. S. Wright.

A sundial calibrated according to the mean of all five azimuths would, therefore, never be more than a little over a degree in error, and one graduated for the Pole would not be much farther out than a sluggish compass. The sundial to be used in this way was, it is believed, first devised by Scott in 1903. Since every party carried a chronometer watch the dial was easy to set and could be held in the hand while on the march.

A description of the instruments used would not be complete without mention of the exceedingly useful "Sledging Tables," which were specially arranged and printed in a handy size.

They were chiefly reprints, either in full or with adaptations, of the tables at the end of 'Hints to Travellers,' by permission of the Royal Geographical Society, forming a book of about 150 pages, strongly bound in cloth. The tables included were as follows :—

1. Value in degrees of Points of the Compass, with log sines.
2. Length of degree of Longitude for parallels from 68° S. to 89° S., in Statute and Nautical Miles.
3. Sun's parallax in altitude. A shortened form of table in 'Hints to Travellers.'
4. Table of Refraction.
   Correction for Barometer reading.
   Correction for Thermometer reading.
   This was arranged so that the pressure and temperature corrections were given as factors of the mean refraction—a form which is hardly so convenient as that in the 'Hints to Travellers.'
5. Log sines of small arcs to each second to 1° 30′.
6. Log sines of small arcs to ten seconds from 1° 30′ to 4° 30′.
7. Table for computing reduction to the meridian in seconds. From 'Hints to Travellers.'
8. Logarithms of numbers to six figures.
9. Table of Natural Sines, Tangents, Secants, etc., for every degree. From 'Hints to Travellers.'
10. Table of Log Sines, Cosines, etc. From 'Hints to Travellers.'

At the end of the book were a number of blank pages for insertion of additional tables or data, the most important being the necessary pages of the Nautical Almanac for the sledging months. Owing to the limited number of Nautical Almanacs, the actual pages were not generally available, and they had to be copied out or, preferably, photographed and pasted in. Other useful tables, which in some cases were cut out of the originals and pasted in, were the A, B and C Azimuth Tables of Blackburne, Hypsometer Tables, Constants in frequent use, etc.

In a pocket at the end of the book was a star chart for the Southern Hemispheres taken from 'Hints to Travellers.'

The field notebooks and other surveying stationery were of the Admiralty pattern, which is not very suitable for topographical survey work.

CHAPTER III.

THE FUNDAMENTAL POSITION OF THE HEADQUARTERS AT CAPE EVANS.

The headquarters of the expedition was situated on a small low cape about 15 miles North of Hut Point, which had been the headquarters of the National Antarctic Expedition of 1900–04. It was considered preferable to make a separate determination of the position of the new station instead of connecting it with the Hut Point station. Observations for this purpose were undertaken soon after landing, by sextant observations of the sun, and again in the first winter by star altitudes and occultations.

In making these observations various difficulties were encountered, and those which were due to the polar conditions are worthy of description for the benefit of future observers in similar circumstances.

Lieutenant Evans was the chief observer during the first winter, and he thus describes his difficulties :

" For observing occultations the 3¼-inch telescope was mounted outside the main hut at Cape Evans, and a semi-circular shelter was constructed round it with provision cases and compressed fodder bales. A portable telephone connected the observer with the time-keeper at the time station inside the hut.

" The equatorial mounting was not absolutely necessary but it was found of great advantage. The points borne in mind for future work of this description are as follows :—

" 1. Trouble due to restriction of mechanical movement caused by the moveable parts becoming ' metal bound ' can be avoided by keeping the instrument in the hut until required for use.

" 2. The frosting of the lenses was the chief trouble. This occurred sometimes when the sky was absolutely clear. They were always more easily frosted when the telescope had been exposed to the outside atmosphere for some time, but if the observations were made shortly after the instrument had been brought out from the hut no frosting took place.

" The methods tried for clearing the lenses were :—

(*a*) Using an ordinary wash leather.
(*b*) A series of wash leathers brought out warmed at the galley fire.
(*c*) Little sticks with drum-stick heads made of wash leather. (Also tried warmed.)
(*d*) Lesin pencil.

"None of these were very efficient, the resin pencil being useless and the little drum-sticks being best in their ordinary state. The best suggestion that can be offered for surmounting this difficulty is to keep the lenses as warm as possible before observing and to have loose fitting covers for object glass and eyepiece.

"In using the sextant the best results were obtained by keeping the telescope in the hut until the sextant was mounted and the images had been brought together with a blank tube.

"With the mercury artificial horizon it was found best to warm up the mercury in its metal bottle on the galley stove as also the metal trough and the glass roof. A light loose cover put over the sextant when not observing helped to prevent the lenses and mirrors from being frosted.

"It should be noted that the frosting is not due only to the breathing of the observer but quite as much to the presence of minute ice crystals in the air.

"Tangent screws sometimes caused trouble when all other difficulties had been overcome. It was generally caused by the clamping surfaces not biting owing to a thin film of ice forming between them, probably due to the breathing of the observer. It was found desirable to wear a very loose Shetland wool comforter wrapped round the lower part of the face."

LATITUDE.

The latitude of the observation station at Cape Evans was determined by means of seven sets of ex-meridian double altitudes measured with the 7-inch sextants belonging to Commander Evans and Lieutenant Bowers.

Two sets were taken soon after the landing on January 15, 1911, when the altitude of the upper and lower limbs of the sun were measured, using an artificial mercury horizon. The other sets were taken on August 4 and 5, 1911, when Rigel and Sirius were observed, and on August 7 when Achernar and Canopus were used.

With the exception of one observation on August 4 and two of Achernar on the 7th of that month, which were evidently erroneous and have been rejected, the observations agree well and each group of observations gives a satisfactorily low mean error. The means of each group do not, however, show so close an agreement. This is to be expected on account of the great difference in the conditions under which the groups were taken. In the summer the temperature at the time of observation was 27° Fahr., while the winter observations were made at temperatures of −22°, −32°, −28° and −28° Fahr. In addition to the temperatures, the difficulties with hoar frost and the necessity for warming the telescope and mercury must all have introduced errors.

In combining these seven mean values the weight of each has been computed from the mean error of the group, but in the case of the first set of observations of Achernar on August 7 the calculated weight of 5·5 has been arbitrarily reduced to 1, since two out of the original five observations had to be rejected on account of wide discrepancies, and consequently the mean error of ± 2·6 seconds deduced from the remaining three observations exaggerates the reliability of the mean value for the latitude derived from them.

The results are as follows :—

Date.	Star.	Corrected Altitude.	Latitude.	r	r^2	Mean Error.	Reduced Altitude.	Mean Latitude.
		° ′ ″	° ′ ″			″	° ′ ″	° ′ ″
January 15, 1911.	Sun.	33 42 17	77 38 28	+ 8	64	± 2·6	33 42 58	77 38 20
		33 42 04	77 38 24	+ 4	16		33 43 01	
		33 41 49	77 38 21	+ 1	1		33 43 03	
		33 41 13	77 38 21	+ 1	1		33 43 02	
		33 40 54	77 38 11	− 9	81		33 43 11	
		33 40 31	77 38 14	− 6	36		33 43 08	
January 15, 1911.	Sun.	33 38 31	77 37 25	−15	225	± 5·5	33 43 53	77 37 40
		33 38 00	77 37 25	−15	225		33 43 52	
		33 37 31	77 37 33	− 7	49		33 43 44	
		33 35 27	77 37 54	+14	196		33 43 22	
		33 34 57	77 37 50	+10	100		33 43 25	
		33 34 27	77 37 51	+11	121		33 43 23	
August 4, 1911.	Rigel, N.	20 40 33	77 37 24	+ 2	4	± 5·5	20 40 33	77 37 22
		20 40 13	77 37 13	− 9	81		20 40 44	
		20 39 21	77 37 13	− 9	81		20 40 44	
		20 37 45	77 37 36	+14	196		20 40 21	
August 5, 1911.	Sirius, N.	28 57 35	77 37 49	−12	144	± 4·96	28 57 35	77 38 01
		28 57 19	77 37 57	− 4	16		28 57 27	
		28 57 00	77 38 01	0	0		28 57 23	
		28 56 49	77 37 58	− 3	9		28 57 26	
		28 55 52	77 38 19	+18	324		28 57 05	
August 7, 1911.	Achernar, S.	45 24 13	77 40 57	+ 4	16	± 2·6	45 21 47	77 40 53
		45 24 46	77 40 48	− 5	25		45 21 38	
		45 26 23	77 40 54	+ 1	1		45 21 44	
August 7, 1911.	Achernar, S.	45 26 31	77 39 29	+ 4	16	± 1·3	45 19 19	77 38 25
		45 27 40	77 38 25	0	0		45 19 15	
		45 30 16	77 38 25	0	0		45 19 14	
		45 31 38	77 38 21	− 4	16		45 19 11	
		45 32 40	77 38 23	− 2	4		45 19 13	
August 7, 1911.	Canopus, S.	40 16 55	77 38 13	− 2	4	± 4·6	40 16 41	77 38 15
		40 16 55	77 38 07	− 8	64		40 16 35	
		40 17 20	77 38 17	+ 2	4		40 16 45	
		40 17 55	77 38 31	+16	256		40 16 59	
		40 13 30	77 38 05	−10	100		40 16 33	

Collecting these results we have :—

Mean Latitude.	Mean Error = M.	$M^2 \times 10^2$.	Weight = W.
° ′ ″	″		
(1) 77 38 20	± 2·6	760	5·5
(2) 77 37 40	± 5·5	3025	1·4
(3) 77 37 22	± 5·5	3025	1·4
(4) 77 38 01	± 5·0	2500	1·7
(5) 77 40 53	± 2·6	760	1·0 (5·5)
(6) 77 38 25	± 1·3	169	25·0
(7) 77 38 15	± 4·6	2116	2·0
			38·0

Taking these weights with the exception of the fifth mean for which the weight 1·0 is employed as stated above, the weighted mean latitude is :—

77° 38′ 24″ S.

with a mean error of ±11·9″.

LONGITUDE.

The longitude of the headquarters station was determined in two separate ways, by carriage of chronometers between Lyttleton and Cape Evans, and by occultations of stars by the moon.

The observation station was situated 30 feet true North of the North-east corner of the hut at Cape Evans, a point about 3 feet above mean sea level.

By Carriage of Chronometers.

The chronometer errors and rate were determined by equal altitudes of the sun at Lyttleton on November 23, 1910, and again by a similar method on returning to that port on April 7, 1911, the observers being Lieutenants Pennell and Rennick, using 7-inch sextants and chronometers A, B and D.

The behaviour of these chronometers over that period may be seen by an extract from the ship's chronometer book as follows :—

	Kullberg, 6617. A.	Kullberg, 5338. B.	Keys, 954. D.
	S.	S.	S.
Lyttleton, November 23, to Lyttleton, April 7	1·025 losing.	1·356 losing.	1·036 gaining.
Cape Evans, January 15, to Cape Evans, February 9 ...	0·92 ,,	2·04 ,,	1·14 ,,

From this it is evident that chronometers A and D had the more reliable rate, so the weights of the resulting longitudes have been distributed as :

2 for both A and D. 1 for B.

The observations at Cape Evans were made by the same officers on January 5, 1911, but Lieutenant Rennick's sights were afterwards rejected as his sextant was found to be faulty. They were made at the observation spot on the gravelly beach with the same sextants as for latitude sights. Upper and lower limbs of the sun were taken and the horizon cover glass was changed round during the observations.

The longitudes resulting from these observations were :—

Chronometers. A.	B.	D.
h. m. s.	h. m. s.	h. m. s.
11 05 29·9	11 05 54·7	11 05 30·6

from which we have a weighted mean for the longitude by chronometers in the season 1910–11 of

11 h. 05 m. 35·0 s. E.

In the season 1912–13 two extra chronometers were available, C and G having been taken on the ship from Cape Adare the year before.

The time at Lyttleton was obtained by telegraph from the Hector Observatory at Wellington. Mr. Charles Adams of the observatory took the sights and sent the signals himself, which were received at Lyttleton by Lieutenant Pennell visually by the deflection of a galvanometer needle. This was done also on the return of the ship, giving the following results :—

Errors on G.M.T.	A. Slow.	B. Slow.	C. Slow.	D. Fast.	G. Slow.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
December 12, 1912 ...	0 14 44·3	0 50 44·8	1 01 03·5	0 25 05·7	3 44 53·3
February 13, 1913 ...	0 15 46·1	0 49 47·1	0 55 32·2	0 26 24·8	3 45 01·5
	S.	S.	S.	F.	S.
Travelling sea rate epoch 63 days ...	0·981 L.	0·916 G.	5·259 G.	1·256 G.	0·130 L.

On arrival at Cape Evans observations were taken by Lieutenant Pennell with sextant and by Mr. Wright with a 4-inch theodolite. The mean of the longitudes using all the chronometers and taking them as of equal value was 11 h. 05 m. 37·0 s. Allowing the weights 1 for season 1910–11 and 2 for season 1912–13, on account of the extra precautions taken in carrying the time, we get a final result of 11 h. 05 m. 36·3 s., or 166° 24′ 05″ E. of Greenwich.

THE LONGITUDE BY OCCULTATIONS.

Observations for time by occultation were made by Lieutenant Evans during the winter of 1911 and again by Mr. Nelson in the winter of 1912. In the latter case, however, the observations were much interfered with by bad weather and only one of his determinations was complete enough to justify discussion.

On the return of the expedition to England the corrected values of the moon's R.A. and declination were obtained from Greenwich and the observations re-computed by Mr. Curtis, from whose report the following notes are compiled.

The results were as follows :—

	h.	m.	s.
I.—Jupiter, June 8, 1911—			
First limb E.	11	05	36·8
Second limb	11	05	37·0
II.—Sagittarii, June 13, 1911..	11	04	51·9
III.—22 Scorpii, July 24, 1912	11	06	33·4

The agreement of I*a* and I*b* is very satisfactory, but the discrepancies of II and III from this considerably exceed the probable errors of observation.

Observation III is not reliable in any case, since the chronometer correction was derived from the sidereal clock correction, which in its turn depended on the azimuth of the fixed mark of the transit instrument about which there was uncertainty (*se* report on gravity observations).

Result I has been adopted for the following reasons :—

(*i*) The agreement of the two results gives it greater weight.

(*ii*) The observations in Result I were taken when the hour angle of the moon was (*a*) 89° 46′, and (*b*) 89° 27′, the accuracy of the result being greatest when the hour angle is 90° and decreasing rapidly as the hour angle diminishes. The hour angle of the moon was 33° 40′ and 12° 15′ for II and III respectively.

The final result for the longitude is therefore :—

By occultations	11 h. 05 m. 36·9 s. E.
By carriage of chronometers	11 h. 05 m. 36·3 s. E.

Mean 11 h. 05 m. 36·6 s. E. or 166° 24′ 8·5″ E.

A comparison with the fundamental position of the 1900–04 base at Hut Point would be of great utility and interest, but, unfortunately, this is not possible. The final mean adopted by Lieutenant Mulock for the base station, which was the bridge of the ship frozen in a few score yards from the shore, was :—

Lat. 77° 50′ 50″ S.
Long. 166° 44′ 45″ E.

No detailed memoir of the survey methods was published by that expedition, so it is not possible to assess a probable value for that determination, and on account of the loss of some of the original notebooks of observations there is no means of finding out the methods used.

Still, a useful comparison could have been made by triangulation down to Hut Point from Cape Evans. As described in the next chapter, this was attempted but did not give a sufficient degree of accuracy to make a comparison of any value.

CHAPTER IV.

SURVEYS CLOSE TO HEADQUARTERS AT CAPE EVANS.

Detailed surveys of parts of the west coast of Ross Island were undertaken at various times, all of which have been used in the compilation of Maps IV to XI. The only detailed map previously published was a plane table survey of a few square miles in the vicinity of Cape Royds, carried out by Professor T. W. E. David in 1908.*

The sources for the compilation are as follows :—

I.—A triangulation from Cape Evans to Turtleback Island, detail with a sextant traverse, carried out by Lieutenant Evans, assisted by Gran.

II.—A theodolite traverse of the Barne Glacier seaward face by Wright.

III.—Extension of the triangulation from Cape Evans to Cape Royds by Wright and Campbell.

IV.—Plane table sheets covering ascent of Erebus, Cape Royds and Cape Barne region and the Hut Point Peninsula, by the writer.

THE TRIANGULATION.

The triangulation was undertaken for the primary purpose of controlling the detailed survey of the coast line immediately North and South of the headquarters, but for a number of reasons it proved insufficient for the purpose.

It was begun in the autumn of the first season, April, 1911, and concluded in the early spring of the following season. The temperatures and the poor visibility were therefore against accurate work.

The base was measured on the sea ice South of the headquarters with a sledgemeter. Eight measurements were made giving the following results :—

Going East.	Returning West.
Yards.	Yards.
1,870.	1,898.
1,868.	1,885.
1,872.	1,899.
1,862.	1,891.

The bad discrepancy between the "going" and "returning" sets has not been satisfactorily explained, but it seems possible that a constant addition may have been made in turning the instrument at the Eastern end. The measurement gives some idea of the order of accuracy of the sledgemeters but was naturally of no value as a base for triangulation. Nevertheless, circumstances, such as the pressure of other duties and finally his illness and departure at the end of the summer, prevented Lieutenant Evans from making a re-measurement, so that a mean of those distances has had to be used for computation, and the final results cannot, therefore, be regarded as satisfactory.

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* Brit. Ant. Expedition, 1907–09. Geological Report, T. W. E. David and R. E. Priestley.

The sledging theodolite (4-inch, vernier) was used for the station observations, the summation error in the only three triangles fully measured being 25″, 01′ 20″, and 05′ 12″. Both verniers were read but on one face only.

It is, therefore, obvious that no use can be made in the future of this triangulation, even if the stations were still recognisable, and further description is therefore unnecessary. It must be remarked, however, that there was nothing in the local conditions to prevent triangulation of a high degree of accuracy and from the experience of this attempt it was evident that with time and the proper instruments a very useful control could be made in this way. The delays due to bad weather would reach a high percentage perhaps for work early and late in the season, but that would be offset to some extent by the high degree of visibility which is characteristic of the climate.

The coast line south of Cape Evans as far as Hut Point was "walked in" by Lieutenant Evans, assisted in places by Gran with a 10-foot pole. The depths of the bays were generally estimated, but most of the points between bays were "cut in" by sextant angles to triangulated points. The most useful portion of this long traverse is the outline of the large glacier tongue, which is published separately in Map No. XI. Many problems with regard to the outline and movement of glacier tongues may be settled by a careful comparison of this map with one to be made in the future, and its errors can be regarded as chiefly those of scale, not of relative position of the features. The small plan of Cape Evans (Map No. VIII) is also based on this triangulation.

In the summer of 1912 the triangulation was extended by Wright and Campbell so as to reach to the Cape Royds district. The observations were made with great care with the 4-inch theodolite, but on account of the unreliability of the first base they have not been as useful as was hoped. They were used to some extent as a control of the plane table sheets which covered the same area.

The traverse of the face of the Barne Glacier was independent of the triangulation and has been used entirely for that part of the coast line.

The plane table sheets were to varied scales and as the results of the triangulation were not known at the time they were controlled only by a preliminary graphic triangulation in each case. Heights were obtained by Abney level or by using occasional sights with the sledging theodolite. The contours were sketched in in the field by interpolation from these spot heights. They are, therefore, hardly more than form lines giving an idea of the shape of the land.

Two running traverses were made by Lieutenant Pennell in the ship to plot the coast line between Cape Royds and Cape Bird. They were done while making a passage and the points were cut in by sextant angles and, where the range was not too great, by the range finder. These traverses have not been used in the compilation of the map, however, as the plane table sheets on a small scale made during the ascent of Mount Erebus proved to be more satisfactory.

The height of Mount Erebus given on the final map is 13,200 feet and is arrived at on the following grounds. Various earlier determinations had been made of its height with these results :—

	Feet.	
Ross, 1842	12,400	Observations from ship at distance over 40 miles.
Discovery Expedition, 1900–04.	12,922	Theodolite observations from mean distance of about 25 miles.
Nimrod Expedition (Shackleton, 1907–09).	13,370	Aneroid and hypsometer on summit.

On the *Terra Nova* Expedition an ascent was made in December, 1912, but on account of a very strong wind at the summit the hypsometer could not be used and the aneroid reading being obviously in error the ascent gave no figure to add to those of former expeditions.

Observations for the altitude of the summit were made by the writer with the theodolite from sea level. All precautions were taken, using both faces, reading the vernier bubble, thermometer and barometer, etc., leaving only the value of refraction undetermined. The result of the computations, using a value of 0·070 for the refraction is 13,110 feet, but this is liable to an error estimated at ±100 feet, due to the use of the unreliable triangulation measurements for the base of the height observations. The observations were made from the flagstaff at Cape Royds and from the summit of Inaccessible Island, and both should be free from irregular refraction as the lines of light do not graze the ground. The distance of the nearer station from the summit is about 15 miles.

There is no means of determining the probable accuracy of the measurements of the *Discovery* Expedition as there is no record of the original observations, but it is considered that they should rank equally with those of 1912, offsetting the greater distance of the earlier stations against the uncertainty of the base length in the latter case.

The hypsometer observation in 1908 was apparently made with care, and as the value of refraction is unknown for the two trigonometrical heights it is thought that the weights should be slightly in favour of the direct pressure measurement.

Giving the hypsometer determination a weight of 2 to a weight of 1 for the other two determinations we arrive at a height of 13,193, and the estimated probable error is about ±50 feet. For the purpose of the map the height is taken as 13,200.

The spot heights on the route up Erebus as far as the Old Crater have an accuracy of about the same order, as they were taken with the aneroid, checked by the hypsometer at every alternate station, and further checked by altitudes with the theodolite from Cape Royds and from three of the upper stations. The distances in this case were taken from the plane table triangulation.

The somewhat indefinite junction between the Barrier surface and the land on the South side of Ross Island is taken from a survey by Dr. E. A. Wilson in November, 1903. The nature of the tide crack on this junction is of importance, as also the direction of movement of the ice and the pressure waves set up by the opposing movements of Barrier and land ice.

The traverse was made by sledgemeter and compass, and the detail is filled in from numerous sketches.

The coast line of the Northern side of Ross Island (Map No. IV) is markedly different from that of earlier maps. It is taken from a running survey by the ship, made on January 3, 1911, during its passage from Cape Crozier to Cape Bird. At least ten people were available for the observations, there was no pack ice to interfere with the courses and rate of the ship and all ordinary precautions were taken to obtain accuracy. The portion from Cape Crozier to Cape Campbell should, therefore, be accurate on the scale used, but the deep bay towards Erebus, which opens after Cape Campbell is passed, was not entered and can only be considered as approximately correct, it being singularly devoid of features to which sextant angles might be taken.

It is important to note that no new fix for the position of Cape Crozier was made, and the value used throughout this series of maps is that used in the *Discovery* Expedition, 1901–04.

Lat. 77° 29′·2 S.
Long. 169° 34′·5 E.

CHAPTER V.

THE SOUTHERN JOURNEY.

So little has been published concerning methods of land navigation in polar regions, that no apology seems necessary for a full account of those used on the polar journey, which were closely followed on all other journeys.

The type of instrument used has already been described, but the numbers taken when the journey began (the party consisting essentially of three units) were as follows :—

4-inch theodolites	3
Deck watches	6
Sundials	4
Liquid compasses	2
Hypsometer	1

Aneroids, sling thermometers and small prismatic compasses.
Sledgemeters.

No sextant or artificial horizon was taken.

The navigation was in the hands of Lieutenant (now Captain) Evans up to the time of his return in charge of the last supporting party, after which Lieutenant Bowers was responsible. Assistance was given at various times by other members of the party, and for the survey of the Beardmore Glacier in particular the assistance of Dr. Wilson's accurate sketching and Wright's photographs proved invaluable. The heavy labour of re-working all the sights and adjusting them was carried out by Lieutenants Pennell and Rennick in 1913, and the map illustrating the journey, though drawn by the writer, is due largely to their labours.

The journey is dependent upon sun sights for latitude, time and azimuth taken with the theodolite. A routine was attempted by which time and latitude sights were to be taken every day in the forenoon and noon respectively, and while the travelling was done at night for the early stages of the journey, this was generally possible. Later on, however, the exigencies of the marching and dull weather interfered very much with the routine, and the rule of taking sights whenever there was a chance came into practice.

There was, of course, frequent comparison of watches, and it may be assumed that the sights on the outward journey over the Barrier are moderately accurate in consequence, but as none of the watches returned to the base without running down, it is impossible to find a mean error and rate, and no full discussion of the behaviour of the watches can be attempted. It must be admitted that the cause of the watches stopping was, in three cases at all events, forgetfulness, in spite of the last word from tent to tent at night being "Wind watches," accompanied by ceremonial. On the other hand, in defence of the transgressors of the navigators' law, it must be said that the day's work, on the Beardmore Glacier, was often 15 or even 18 hours in length and was not only of the hardest manual kind in itself, but included frequent disturbing incidents such as falling to the length of the harness into a crevasse. Under such circumstances, even the navigators themselves occasionally nodded.

The dead reckoning as given by the sledgemeters in conjunction with the courses given by sundial or liquid compass were generally in satisfactory agreement with the sights while on the level Barrier. On the glacier and the polar plateau the sledgemeter distances were far from accurate on account of the rough travelling.

In order to simplify navigation on the return journey over the Barrier, cairns* of snow-blocks were built at intervals varying from three to five miles, and as their line was followed by all returning parties, there are very few cases of the position of the same place being observed twice over, and hence rough checks for chronometer rate from that source fail also.

The greater part of the Barrier journey being out of sight of land, the survey work resolved itself into simple navigation and observations of azimuth to determine the variation until the land near the Beardmore Glacier was in sight.

Evans' plans for mapping the glacier were very complete but were, unfortunately, quite upset by the prolonged "wet" blizzard, which delayed the whole party so seriously near the mouth of the glacier. In addition to the delay and consequent need for longer hours of marching, all hands were now called upon to man-haul the sledges in knee-deep snow. The survey work by Evans and his helpers then resolved itself into a few rounds of angles to peaks, etc., from camps whose position was obtained by sun-sights or dead reckoning and a series of notes of transits and even sundial bearings gathered during short halts.

It is clear, therefore, that the survey is simply a rough traverse and, as fully explained in the description of the map of the Southern Journey, does not pretend to great accuracy. On the upper part of the glacier weather and surface were more kindly, and some useful corrections to Marshall's map (British Antarctic Expedition, 1907–09) were made.

Once fairly on the plateau the party, now reduced to two units, resumed ordinary navigation methods with the added detail of determining height. This was done by hypsometer and aneroid, but, unfortunately, the thermometer of the former was broken before the divide was reached.

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* These cairns were built by members of the pony parties who had a certain amount of spare time after each march ; no man-hauling party ever had reserves of strength for raising cairns. The cairns in almost all cases were still distinguishable after three months of summer weather.

A more detailed account of the methods adopted may be given from the interesting stage when the last supporting party turned back in

Lat. 87° 32′ S.
Long. 160° 41′ W.

as given by three chronometer watches.

Polar Sights.

Two watches, S and T, were taken on and compared on alternate days. At the third comparison, on January 9, the alarming discovery was made that one of the watches had lost or gained 26 minutes during the previous night. An observation for longitude was made the same evening, and this showed that S had unaccountably lost 26 minutes. After that, comparisons of watches were made every day, and these showed that the rate of S had become somewhat irregular, and T watch was used for all sights.

As they neared the Pole, Bowers became indefatigable in taking observations, as is shown by the list of observations following :—

Sights on Nearing the Pole.

January.	Latitude.	Longitude.	Magnetic Variation.
9	×	×	×
10	×	×	×
11	–	Cloudy.	—
12	×	×	×
13	×	×	×
14	×	×	×
15	×	×	×
16	×	×	×
17	4	–	–
18	2	At the Pole.	

They were marching on the meridian of 160° E. and varied very little from it. Sights for variation were taken constantly, and the compass was fairly reliable so far from the Magnetic Pole.

On reworking these sights, only one error of importance is discoverable. On the 13th, in Lat. 89° 8′ S., there is a mistake in applying the watch correction, which places the party on the 163rd meridian instead of the 161st, only a matter of $2\frac{1}{2}$ miles in that latitude. But Bowers was obviously worried over the apparent alteration of course and took the next longitude sight on the 15th with great care, finding himself back on the 161st meridian again.

At the lunch halt on the 17th an observation for latitude was taken giving the result 89° $53\frac{1}{2}'$, $6\frac{1}{2}$ miles from the Pole. This is the first sight in which the reduction to meridian is omitted, there being, of course, no such thing as a circum-meridian sight at the Pole. The party therefore marched for 6½ miles on the same course as before and camped about seven in the evening. It was during this march that they discovered the black flag left by Amundsen, their first intimation of their loss of priority.

The observations which followed are worthy of record, not only as an instance of the extraordinary care with which the navigation was carried out, but also as a record of endurance on the part of Bowers. A discussion of these observations gives a very good idea of the order of accuracy attainable with 4-inch light theodolites under unfavourable circumstances. The temperature on camping was —21° F., and there was a wind of force 5 blowing, yet he set out to make sure of his position in the following way.* Immediately on reaching camp he took two complete sets of observations, reading both circles, four positions of the sun with instrument face left and then four more face right. This unusual method of observing, which would not be permissible with normal circum-meridian sights, is, of course, quite sound in the unique position of the observer in this case. F.R. and F.L. observations were worked out independently and gave the results :—

F.L. set	89° 57′ 03″
F.R. set	89° 56′ 47·5″
Mean	89° 56′ 55″

Two hours later, that is to say, immediately after concluding his computations and a meal, another set was taken, this time giving a result of 89° 57′ 01″. By the time this was completed it was about 10 o'clock (160th meridian time). The next observation was at 2 o'clock in the morning, a set of four sights, both circles read, and the fatigue of the observer is evident in the large number of arithmetical mistakes made in the working out. Most of these were detected and alterations made, but the error of the watch was not applied. On re-working with all corrections the result is 89° 59′ 12″, showing a great discrepancy from the other sights at this camp.

At 7 o'clock in the morning another complete set was taken, giving 89° 56′ 54″, and from all these the most probable bearing and distance of the Pole was worked out to be a little over 3 miles S. 80° W. by compass. (Variation being 180° naturally.)

From this camp Amundsen's tent could be seen, lying S. 47° W., and it was visited on the march to the final camp. At 1 o'clock camp was pitched " on Pole," and the sights reproduced in facsimile (Plate 2) were taken. The temperature was —22·4° F. and barometer 20·34°. The wind was blowing from S.S.W. (as from 160th meridian), force 3.

There is nothing in the diaries of the party about this final observation for fixing the Pole, but the internal evidence of the page is not without interest.

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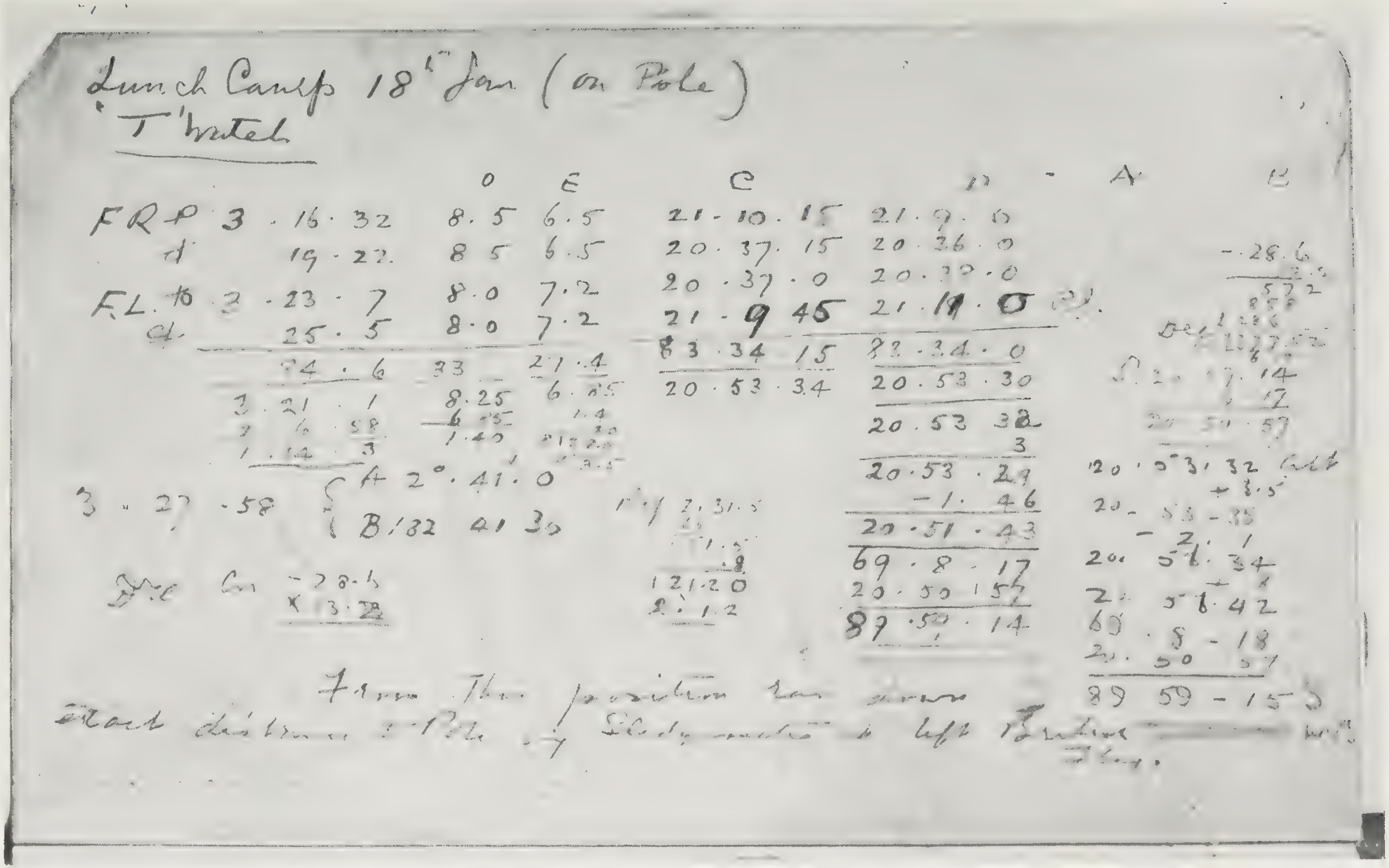
* Wilson says in his diary of this day : " . . . the coldest march I ever remember. It was difficult to keep one's hands from freezing in double woollen and fur mitts. Oates, Evans and Bowers all have pretty severe frost-bitten noses and cheeks. . . ."



Lunch Camp 18th Jan (on Pole)

'T' watch

O E C D - A B

FRP 3 . 16 . 32 8 . 5 6 . 5 21 . 10 . 15 21 . 9 . 0

19 . 22 8 5 6 . 5 20 . 37 . 15 20 . 36 . 0

FL. 3 . 23 . 7 8 . 0 7 . 2 20 . 37 . 0 20 . [illegible] . 0

25 . 5 8 . 0 7 . 2 21 . 9 45 21 . 19 . 0

84 . 6 33 27 . 4 83 . 34 . 15 83 . 34 . 0

3 . 21 . 1 8 . 25 6 . 85 20 . 53 . 34 20 . 53 . 30

20 . 53 32

3

20 . 53 . 29

A 2° . 41 . 0

3 . 27 . 58

B 182 41 30

−1 . 46

20 . 51 . 43

69 . 8 . 17

20 . 50 . 57

89 . 59 . 14

− 28 . 6

20 . 53 . 32

20 . 53 . 35

− 2 . 1

20 . 51 . 34

20 . 51 . 42

69 . 8 . 18

20 . 50 . 57

89 59 − 15

From this position [illegible]

[illegible] distance [illegible] Pole [illegible] left British [illegible] flag.

Plate 2.—Facsimile of the South Pole observation.

To face p. 26, Report on Maps and Surveys.

The observed figures are in Captain Scott's handwriting; in fact, he has initialled a correction, so that Bowers was probably observing, though he usually booked his own observations. Captain Scott then worked out the sight first, making one or two slight mistakes. For instance, it will be noted that he applies the wrong sign to the bubble correction, uses the refraction correction from a computation made in the morning of that day and does not apply the correction for parallax.

Bowers then re-works the sight, applying all the corrections for which his sledging tables provided the data. His result, by reason of the compensation of signs in Scott's mistakes, differs by only one second, and no doubt in their weary state they were greatly pleased with the close agreement. It placed them some 1,500 yards from the Pole, and the formality of reaching it as exactly as sights permitted was gone through, as noted in Bowers' handwriting later: "From this position ran down exact distance to Pole by Sledgemeter and left British Flag," a simple phrase which is, to those who knew him, an epitome of his whole character.

It would be of great interest to discuss the probable error of this position, and, as far as the accuracy of the altitudes given by the instrument is concerned, it can easily be done. Unfortunately, the error in the value of the sun's declination used depends upon the error of the chronometer, and as this watch did not return to the base (it was in fact recovered with the bodies) no assessment of its probable error at that time can be made.

The fact that no less than five sets of observations for latitude were taken at their 69th camp, extending over twelve hours, provides us with a certain amount of data upon which to find the probable error as follows:—

Mean of Bowers' workings	89° 57′ 20″.
Mean of re-workings by the writer with certain added refinements	89° 57′ 25·4″.

Including the bad observation taken at 2 in the morning, which has a residual of 106 seconds, we find that the—

Probable Error of the Mean is ±19″; and
Probable Error of Single Observation is ±37″.

From this result we may assume that as far as the instrument is concerned the accuracy of the Pole Observation itself is of the order of ±30″ at worst.

As to the error of the chronometer, the few methods of checking it which are available give it an uncertainty of at most a few minutes of time, adding something for the uncertainty of the longitude of Cape Evans, and as the change of declination in one hour at that date was only 30 seconds of arc, the error in latitude due to faulty time would be small.

From the fact that Amundsen was at the same place but one month before, we have an opportunity of estimating the respective advantages of the sextant and theodolite for polar navigation, a point which periodically comes up for discussion.

Amundsen's equipment at the Pole apparently consisted of two sextants (size not stated, but reading to 10″ and obviously good ones) and both a glass and a mercury artificial horizon. Comparatively few observations for latitude or azimuth were made on the plateau approaching the Pole, the party evidently relying on occasional values of the variation and using the compass. At all events, no observations were made between 86° 47′ and 88° 16′, a distance over which the British party had taken 5 observations.

Amundsen therefore was not surprised to find himself off his chosen meridian and passing the pole position on his left. At the first warning of this, very careful observations were made by two observers for the sun's altitude every hour for 12 hours. The result was to place them some 5 miles from the Pole, and the distance was run down and their spare tent raised. Here observations were taken every hour for 24 hours with two sextants. They reported haze and irregularities in the refraction, but the weather "grand," so we may presume the general conditions were good. As a result, they found they were still not at the Pole, and, as at the last camp, three men went out in different directions and set up marks at a considerable distance from the observation spot, $12\frac{1}{2}$ miles in the first case and 4 miles in the second. One of these marks was within 1 mile of the British pole and was taken by Scott's party for the Norwegian "pole."

When these sights were re-worked in Norway, the mean position of the tent which was left came to 89° 58′·6. By the British observations the same position agrees within half a minute and that seems to represent the general agreement, which it is to be noted is of the same order as the probable error of the pole position.

Amundsen's party had four observers, and the total number of altitudes taken while fixing the Pole area was about sixty, spread over some 48 hours. The theodolite altitudes were eighteen, counting each face of the instrument, one observer only, in 24 hours.

The diagram (Fig. 1), showing the plotted courses and positions of the two parties, brings out the importance of accurate time on which depends the course along the meridian. The British party with frequent observations managed to pass the Pole within only 3 miles, the Norwegians with less frequent observations missed it by some 6 miles.

The close agreement of the final positions will probably confirm the belief in each instrument by its respective supporters, though for general utility and ease of manipulation the theodolite must claim first place.

The navigation on the return journey calls for no technical remarks, but the dauntless Bowers continued his observations at average intervals of two days up to February 27, that is to say, even after they had lost Petty Officer Evans and were on the line of Barrier cairns.

It will be noted from the facsimile of the polar observations that an ordinary notebook was used, and that was the practice throughout the expedition. It is questionable whether this is wise, and although special forms of angle books, etc., would add to the weight, probably they would save time and add to the value of the observations. For rounds of angles to objects there are so many possible forms in which to record, that some standard form is needed if the best use is to be made of observations.

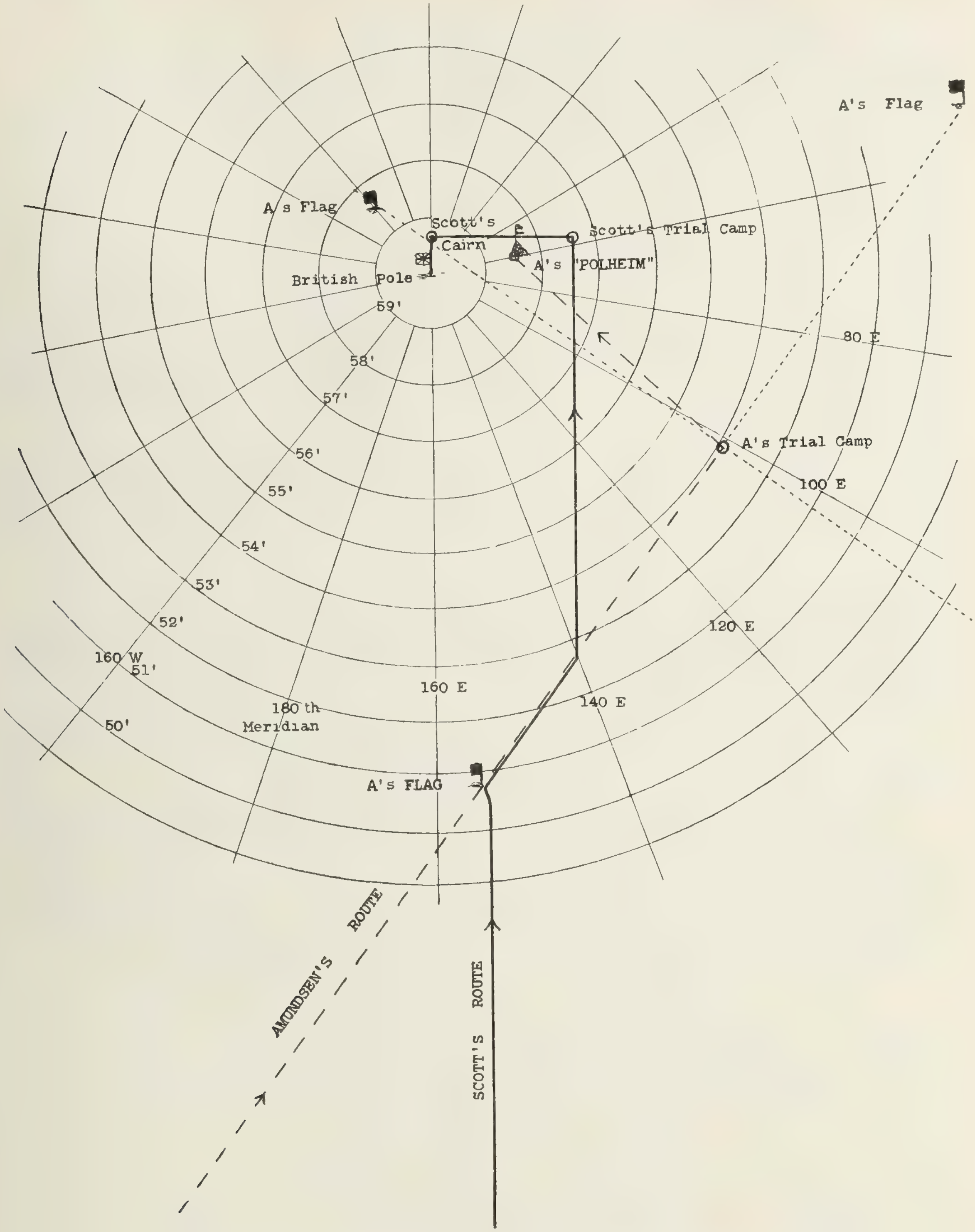


Fig. 1.—Routes of British and Norwegian parties at the South Pole.

A note on methods of navigation in thick weather may not be out of place here, since the most trying times for all the Barrier parties were those when a " grey day " meant the disappearance of all features, including the horizon, and a ceaseless strain on the eyes of the man directing the march. On such occasions the sundial and direction of the sastrugi both failed as a check on the direction, and only the wind direction and the compass could be used. The former, when blowing briskly on the open Barrier, was extraordinarily constant in direction for long periods, but unless the direction of march was into the wind, it was not easy to steer by. The compasses for this purpose had a rather bulky spirit-filled bowl. On account of the low horizontal force directing the needle and the heavy balance weight required on it, successive readings often differed by several degrees, and, in addition, it had to be set on the snow to get a reasonably good reading. When a man could be spared from other duties for keeping direction, this was no great bar, as he could stop occasionally to take a bearing and then catch up, but for ordinary man-hauling the stopping to read the compass was a great nuisance. Having the compass on the front of the sledge so as to be seen without stopping is a useful variation and was practised with success by Amundsen, whose party ran on ski beside the dog-sledges.

It was in consequence of this difficulty of reading the compass that the navigator of the day usually relied on steering as much as possible by faint shadows or even cloud patches on his route, and the strain of keeping them in view was responsible for a great deal of the snow-blindness which was usually the lot of the man who set the course on such days.

The sledging compass deserves rather more attention that it has yet received, and it should be possible to design one for use in the hand if necessary, even if a gimbal arrangement had to be adopted.

The marking of the outward route by cairns or even by dried fish, as used on occasion by Amundsen, is a partial solution of the difficulties of navigation, but it can be practised only by parties with animal power for the hauling.

The marking of depots is another matter closely connected with navigation. Usually a large snow cairn and a black flag on a long bamboo has been used as the sole mark, but here again Amundsen introduced an improvement possible to all parties with time to spare, which consisted in laying out a series of marks, suitably spaced, on either side of the depot for some miles at right angles to the route.

CHAPTER VI.

DESCRIPTION OF MAPS.

MAP A.

ANTARCTIC REGIONS.

PROJECTION: POLAR EQUIDISTANT.

This map has been inserted as a general guide to the situation of the other maps of the series and has been compiled from the best sources available, but no attempt has been made to give the most recent information except in the case of ocean currents.

The arrows refer to definite observations of currents or drifts and are some guide to the movements of icebergs and pack-ice. For the same reason the drifts of various ships beset in the ice are plotted.

The continuous outline of the supposed coast has not been drawn, and the wavy line simply represents the limit of ship exploration in the various sectors.

The tracks of the *Terra Nova* are not plotted on this map, as they did not differ in any marked way from those of several other exploring ships outside the Antarctic Circle.

The following notes of her passages near the doubtful islands, Emerald Island and the Nimrod group, are given as negative evidence of some value :—

EMERALD ISLAND.

March, 1911.

Passed under sail *West* of the assigned position distant about 18 miles.

Noon, March 15	58° 25′ S.	161° 22′ E.
Noon, March 16	58° 46′	162° 31′.
3 p.m., March 16	56° 34′	162° 45′.
9.16 a.m., March 17	55° 54′	163° 38′.

During 15th. Wind—Westerly. Moderate ; Passing showers, overcast.

During 16th. Wind—Westerly. Fresh to strong, dropping light in first watch. Overcast ; No rain, but misty in afternoon up to Fog Intensity 1.

During 17th. Wind—Westerly. Light ; cloudy ; clear weather till Noon.

March, 1912.

Passed under sail *Eastward* of the assigned position distant about 18 miles.

Noon, March 22	58° 38′ S.	161° 31′ E.
9.33 a.m., March 23	57° 30′	163° 12′.
1.03 p.m., March 23	57° 14′	163° 23′.
7.46 a.m., March 24	56° 05′	165° 21′.

A South-westerly wind, strong to a gale, was blowing the whole time with frequent squalls, an overcast sky, and on the 22nd and morning of the 23rd occasional snow flurries; though on the whole it was clear till the afternoon of the 24th, when snow set in.

Nimrod Islands.

March, 1913.

The ship's positions in the vicinity of the position assigned to this group were as follows :—

March 22.	8 a.m.	56° 20′ 6″ S.	160° 22′ 5″ W.	
	Noon	56° 12′ 3″	159° 55′.	
March 23.	0.20 a.m.	56° 03′	158° 07′.	Sounding 2,348 fathoms.
	9.11 a.m.	56° 01′ 9″	157° 27′	
	Noon	56° 01′ 9″	156° 24′ 6″.	
	3.16 p.m.	56° 01′ 9″	155° 52′.	
	6.10 p.m.	56° 02′ 3″	155° 36′.	
March 24.	0.15 a.m.	56° 02′ 3″	154° 34′.	Sounding 2,125 fathoms.
	Noon	55° 55′ 3″	152° 39′.	

Full Moon was on March 21.
Moon's declination on March 23, 10° 0′ S.

During the above time there were light winds and remarkably clear weather for this ocean; the meteorological observations for 4 p.m., 8 p.m., midnight, 23rd; and 4 a.m. and 8 a.m. on the 24th showing a cloudless sky. The bright moon the whole of the nights would have allowed land to be seen at a considerable distance.

MAP I.

ROSS SEA SECTOR OF THE ANTARCTIC.

This map is not intended to do more than furnish a background for the data of surface movements and soundings of the Ross Sea, and the land features are generalised.

Projection.

The map is drawn on the polar equidistant projection, since the distances of chief importance are those in a general meridional direction. The exaggeration of the scale along the parallels is less than 3 per cent. on the 70th parallel.

Sources.

The coastline is compiled from the maps of the *Discovery* and *Nimrod* Expeditions, except where additions or corrections could be made from the present expedition. The strip of coast known as Oates' Land is entirely new, but apart from amended surveys of Robertson Bay, Evans Coves, Granite Harbour and the face of the

Barrier, there is nothing fresh, and these all appear on a larger scale on other maps in this series.

The data for the hydrographic information are also from varied sources. Those which are new are from the three cruises of the *Terra Nova*, and a good deal of detailed information has been gathered from the original records of the *Discovery* Expedition.

Former Surveys.

The first survey of the Victoria Land Coast was made by Ross in 1841, and a few of his determined points still stand, but the real foundations of later maps are the ship traverses of the *Discovery* carried out, with assistance from other officers, by Lieutenant Mulock. The work of the *Southern Cross* two years earlier remains only in the deep bay North of Terra Nova Bay. No serious hydrographic surveying was undertaken by the *Nimrod* in 1907–09, but important corrections to the coastal detail were made by Dr. Mawson of that expedition during a sledge journey up the coast.

A great deal of information on minor points, such as harbourage, etc., has been collected by all these expeditions, and it has been the writer's endeavour to summarise this in this description.

THE VOLCANIC ISLANDS.

Under this heading come a number of off-shore islands, which to the exploring expeditions have been of little interest in comparison to the vast continent behind them, but to the navigator in general and to the cruising whaler in particular these are of more than ordinary interest. They are, therefore, described as fully as possible below.

BALLENY ISLANDS.

Very little is known of this group of islands and even their position on the map cannot be said to be quite satisfactory as yet. They lie between the parallels of 66° S. and 68° S., and the meridians of 162° and 166° East Long., and consist of five islands extending in a general N.W. and S.E. direction. (*See* Fig. 2.)

They were first discovered by John Balleny in February, 1839, who approached them from the East, and this is the only time that the whole of the group has been clearly seen. The commander of his cutter, the *Sabrina*, managed to land on Buckle Island for a minute or two and at the same time they " plainly perceived smoke arising from the mountain tops." The individual islands were named after the merchants who joined with Mr. Enderby in sending out this expedition. Balleny was particularly careful to fix the position of his ship while within view of the islands, but on account of thick weather his sights were not very satisfactory and the relative position of the islands to each other was not established.*

Consequently, when in 1841 Ross sighted islands somewhat to the south-east of Balleny's positions he took them for a separate group and named them the Russell Islands.

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* Antarctic Manual, 1901. Log of John Balleny. Also log of his second mate, McNab.

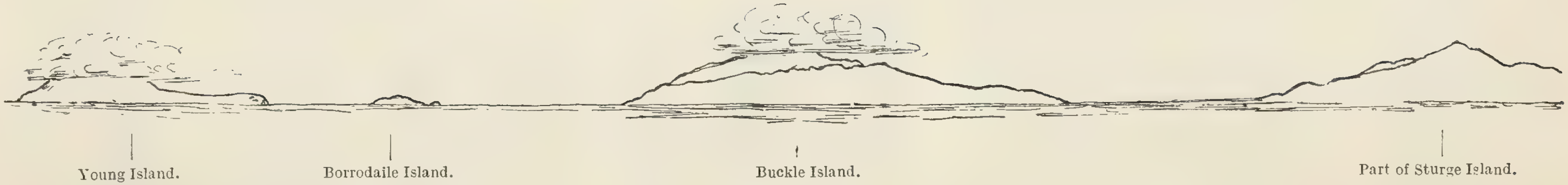
Young Island.
Borrodaile Island.
Buckle Island.
Part of Sturge Island.

Fig. 2.—Four of the Balleny Islands seen from the west. The *Discovery* passed between Sturge Island and Buckle Island. Row Island was not seen. (After an outline sketch by Dr. E. A. Wilson, March, 1904.)

The double discovery led to considerable confusion, which was further complicated by the next visit of which there is a full account. This was during the voyage of the *Southern Cross* under Borchgrevink in 1898, and what was seen of the islands is very clearly described by Bernacchi, one of the members of the expedition. The ship approached within 40 miles of Buckle Island in very clear weather which enabled them to sketch the outline of the island and observe " dark volumes of smoke " issuing from the lower eastern end. (*See* Fig. 3.) This fact and the description of the sheer cliffs capped by an ice-sheet seem to indicate that it was Buckle Island, although from the position of the ship one would have expected the highest of the group to have been visible also. A fortnight later, while still in the pack, they sighted another island which they took to be Russell Island, the position agreeing with that of Ross's discovery. The outline sketch made of this island agrees in general with what is now known of Sturge Island, though the estimated height of the peak, 10,000 feet, was too great.*

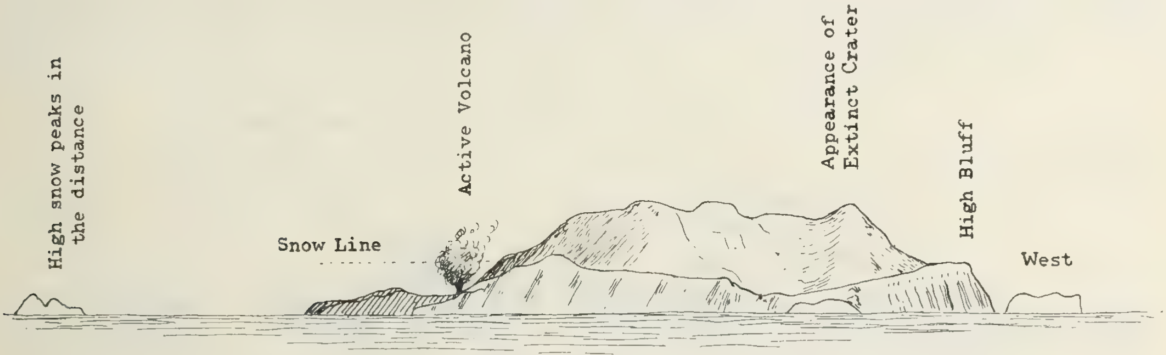

Fig. 3.—Buckle Island, in the Balleny Group, from the north. (After a sketch by L. Bernacchi, from the *Southern Cross*, January, 1899.)

The general confusion of names and positions was finally cleared up by Scott in the *Discovery* in 1904, who passed through the group with a clear sea, and the positions now on the charts are the result of the survey made at that time by Lieutenant Mulock, while the names are a selection of the names given by Ross and Balleny. Bernacchi was on this expedition also and probably was largely instrumental in settling the problem of the discrepancies.†

The most southerly island, Sturge Island, is the largest, being nearly 30 miles long and about 8 miles broad. Like all the others in the group it is covered with a thick mantle of ice, and this seems to descend to sea level at every break in the cliffs, forming huge fan-shaped tongues which project a mile or so from the land itself. This is the most distinctive feature of the whole group and is direct evidence of the much greater precipitation in these latitudes than farther to the south.

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* 'To the South Polar Regions,' by L. Bernacchi, 1901.

† 'The Voyage of the *Discovery*,' R. F. Scott, 1905, vol. ii, p. 390.

The island seems to be singularly unapproachable from the north and east on account of the vertical rock cliffs ; there is no low land and no inlets are visible from seaward. Some of the glacier tongues do enclose large areas of smooth water which might provide temporary shelter, but the anchorage would probably be very bad and the proximity of the steep cliffs would give rise to fierce irregular gusts.

The highest point of the island has been named Brown Peak (Balleny) or Russell Peak (Ross) and is a rounded dome completely covered by its ice cap, about 5,000 feet high.

Buckle Island is the next to the north, lying about 30 miles N.W. of Sturge Island. The *Discovery* did not approach this island closer than about 15 miles and the weather being dull and clouds being low no very clear view of the western side was obtained. Balleny's landing was made on the north-east side by jumping on to some rocks at the base of a cliff, and he records that there are no landing places to be seen on any of the islands. From the sketches of Dr. Wilson, made from the *Discovery*, there seem to be some small coves on the western side which possibly may enclose a beach. (*See* Fig. 4.) Balleny records large numbers of penguins while he was waiting in the fog to the east of the group, also many feathers floating on the water, and this may conceivably be interpreted as signs of a penguin rookery somewhere on the islands, in which case there must be places suitable for landing from a boat. Close to the southern end of the island there are at least two small rocky islets and from one point of view the island itself appeared to be deeply indented or perhaps even separated into two islands, but the visibility was too poor to be sure of this. Incidentally, no signs of volcanic activity were seen by the *Discovery*.

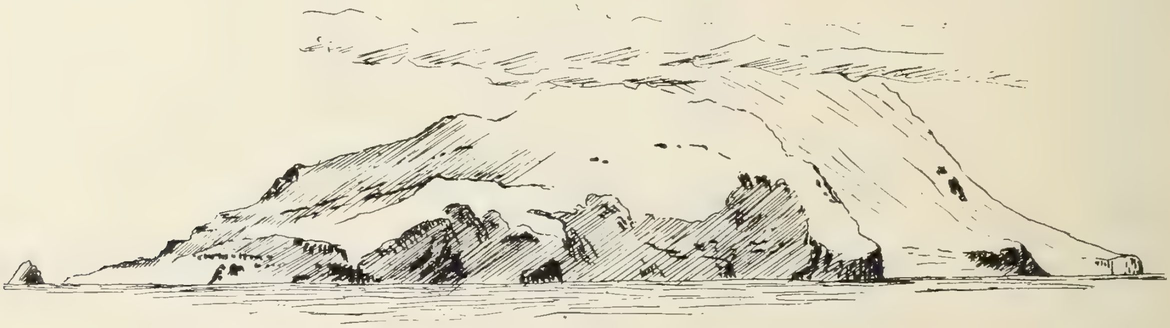

Fig. 4.—Buckle Island, one of the Balleny Islands, from the south, distant about 15 miles. (After a pencil sketch by Dr. E. A. Wilson, from the *Discovery*, March, 1904.)

Borrodaile Island, the next to the north, is the smallest of the group and is low but also covered with an ice cap. At its eastern end there is a remarkable pinnacle of rock which Balleny describes as rising like a lighthouse from the sea.

The next island is Young Island, low at the eastern end but rising to the symmetrical summit of Peak Freeman, which Balleny estimated as 12,000 feet in height. The summit was covered by cloud at the time of Scott's visit, but judging from the lower slopes this estimate of height would appear to be exaggerated, though it is undoubtedly the highest island of the group. The most northern of the islands is called Row Island and has not been seen since Balleny's visit. This is perhaps not surprising as he describes it as low and featureless, but for that very reason it may prove to be the most accessible for landing and for shelter.

The group in general is of great interest as being the continuation of the line of volcanic action which follows the west side of the Ross Sea basin throughout its length and from the fact that it still shows signs of activity.

Its position astride of the Antarctic circle puts it on the same latitude as Adelie Land and the land to the west of it for at least 1,000 miles, but whereas those lands are subject to the terrific southerly gales from the continental plateau behind them the Balleny Islands appear to be just within the range of the Westerlies, as well as of the South Easterlies which bring the pack ice up from the Ross Sea. The recent drift of the *Aurora* confirms what was expected, that this pack passes through and is often hung up by the Balleny Islands, and this accounts to some extent for the difficulty in approaching them. On the other hand, there should generally be a clear sea in the immediate lee of the islands, as was found by the *Discovery*. The heavy precipitation shown by their thick ice-caps, their general inaccessibility and their apparent lack of sheltering inlets all seem to condemn these islands to rare visitations. On the other hand, ships have always reported their vicinity as abounding in whales, and should a future expedition chance to find reasonable shelter in the group it might well form a centre of operations for wooden whalers in time to come.

The *Terra Nova* passed close to the Westward of the group in 1911 and close to the Eastward in 1912 and 1913. On each occasion fog and cloud were so persistent that no bearings of use could be taken.

On March 5, 1911, the ship passed over the charted position of Young Island, while the island was 6 or 7 miles on her starboard and to the Eastward. The day was fine but clouds hung persistently all round the islands, and no useful bearings were obtained.

Allowing that Young Island was passed 6 miles off, this would make it lie about 17 nautical miles to the eastward of its charted position.

Row Island was not seen at all.

The ship's positions fixed astronomically on March 5 were :—

10·09 a.m.	66° 43′ 5″ S. 161° 20′ 5″ E.
2·03 p.m.	66° 34′ 3″ S. 161° 42′ 5″ E.
5·25 p.m.	66° 19′ 1″ S. 161° 41′ E.
10·00 p.m. .. .. .. D.R. from 5·25 p.m. ..	66° 06′ 1″ S. 161° 09′ E.

Scott Islands.

Lat. 67° 24′ S. Long. 179° 55′ W.

These two small islands were discovered by Colbeck in the *Morning* in December, 1902, and were surveyed at the same time by Mulock, from whom the following particulars are taken. (*See* Figs. 5 and 6.) The larger island is about 600 yards long by 250 yards broad and rises to about 130 feet above sea level. The smaller island is a mere pillar of rock rising perpendicularly to a height of over 200 feet. There are two small beaches, one on the N.W. and one on the N.E. side, but both shelve rapidly and are encumbered by submerged rocks so that on this occasion a landing could not be made on them but was effected on some low rocks on the S.E. point, from which specimens of olivine basalt were obtained. The main island is covered with snow, thinly on the Northern end but down to sea level on the Southern.

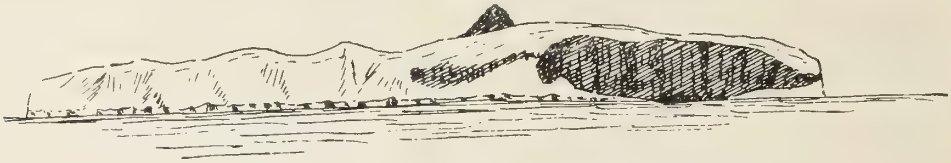

Fig. 5.—Scott Island from the east. (After a sketch by Mulock.)

The islands are truly oceanic, a sounding being taken when only ten miles north of them and giving no bottom at 1,000 fathoms, but the fact that they are only about 300 miles from both the Balleny group and from Cape Adare leads one to suspect that they are an outlying and subsidiary manifestation of the same volcanic period.

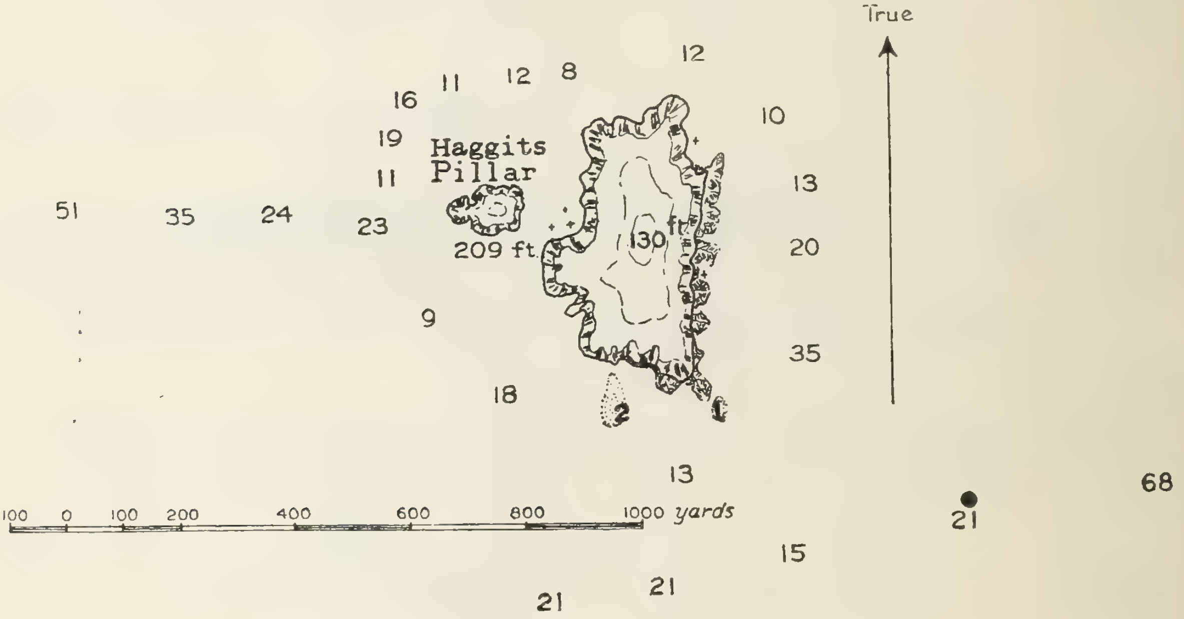

Fig. 6.—The Scott Island. Taken from the survey by Mulock.

The Possession Islands.

This is an interesting group of nine islands and islets in latitude 72° S. a few miles to the east of Cape McCormick, varying in size from 3 miles in length to mere pillars of rock. They were first found and visited by Ross in 1841, who landed on the N.W. island of the group and took possession of South Victoria Land from there. (*See* Fig. 7.) Other landings on the same island have been made by Borchgrevinck in 1894 and 1899, and by Colbeck in 1903. The south-eastern end of the island is high and steep-to, culminating in Peak Archer, estimated at 300 feet high and usually bare of snow, but the greater part of the island is low and usually has a thin covering of snow. The north-eastern side of the island presents a low cliff to the sea for most of its length, but Colbeck's party found a small stony beach on that side which shelves rapidly and is not well adapted to landing from boats. A landing can generally be made on the south-western side where there is a long stony beach, shoaling very gradually with many submerged boulders. There is a large Adelie penguin rookery on the island, occupying most of the flatter part.

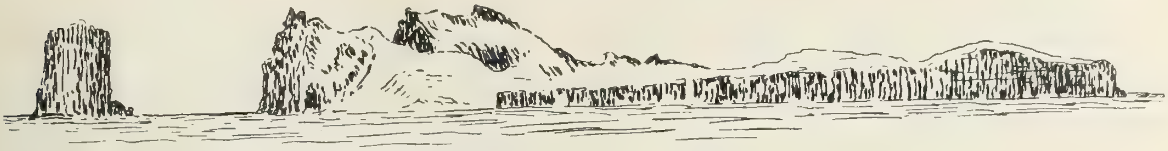

Fig. 7.—The North-Westerly Island of the Possession Islands Group. Seen from the south-east. The landing beach is on the western side. (After a pencil sketch by Dr. E. A. Wilson.)

No other landings have been made in the group but a beach was observed on the middle large island from the masthead of the *Morning*, also on the western side. (*See* Fig. 8.) The islands consist of olivine basalts and palagonite tuffs, some of the latter being arranged in horizontal beds, the whole marking an important extension to the east of the volcanic activity which was responsible for the whole of the Cape Adare peninsula. Owing to the nature of the rock the islets are in the form of pillars and arches two of which are figured.* (Figs. 8 and 9.)

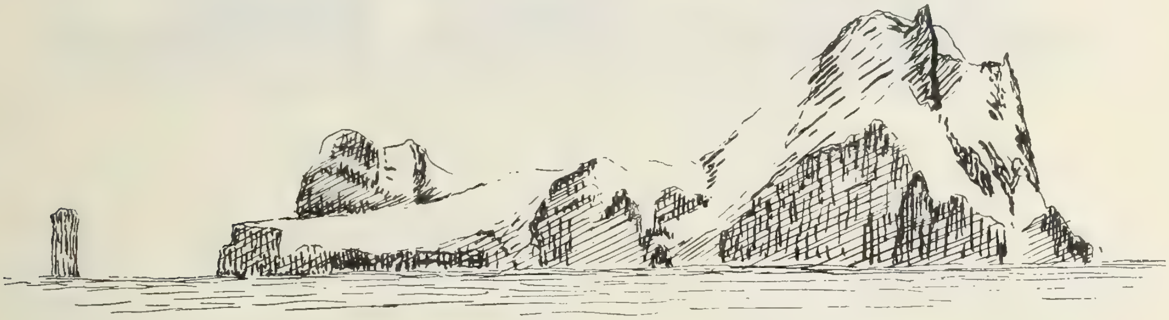

Fig. 8.—The Middle Island of the Possession Islands Group. Seen from the north by west. There is a small beach on the western side. (After a pencil sketch by Dr. E. A. Wilson.)

The channel between the islands and the mainland has been passed by several ships and appears to be free from rocks and shoals, but a tidal current is always met with, setting north and south with flood and ebb, the north setting current being the stronger, recorded up to 3 knots. In consequence of this the pack ice is liable to block the channel or interfere with its navigation.

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* Photographs of some of the Group are to be found in 'Album of Photographs and Sketches, National Antarctic Expedition, 1901–04,' published by the Royal Society, 1908.

Coulman Island.

Situated in Lat. 73° 30′ S., just where the coast of the mainland runs to the west, this island represents an outlier or relic of the volcanic activity which built up the whole of the coast to the north as far as Cape Adare. In this key position the island is of peculiar importance in determining the direction of the currents and drift of the pack ice. It is about 15 miles long and 9 miles broad and at its highest point rises to about 2,000 feet above the sea.

Discovered and named by Ross in 1841, though he was unable to approach it closely, it has since been sighted by most ships sailing into the Ross Sea, and two landings have been made under the cliffs of Cape Wadworth at its northern end. Its present position and shape on the chart are due to the surveys of the *Discovery* under Scott. (*See* Fig. 10.)

It is separated from the mainland on the north by a strait about 10 miles across, while on the west it is separated from the Lady Newnes Barrier sheet by a narrow passage, which has not yet been traversed, and in fact has not received the attention which it deserves. This barrier, though so much smaller, seems to be a replica of the Ross Barrier. Its face to the west of Cape Wadworth is sheer, except in the inlets, and varies from 80 to 150 feet in height, and its surface undulates in waves similar to those of the Ross Barrier in the vicinity of Ross Island. Nothing is known of its movement or its sources, but the proximity of Coulman Island at its corner forms a most inviting point from which to make measurements, either by noting the width of the passage between the ice face and the island, or, better, by erecting a cairn and tall bamboo pole on the barrier itself and fixing it by reference to the land near by. The whole operation might have been done by the two ships which have penetrated into the inlet and the chance should not be missed again.

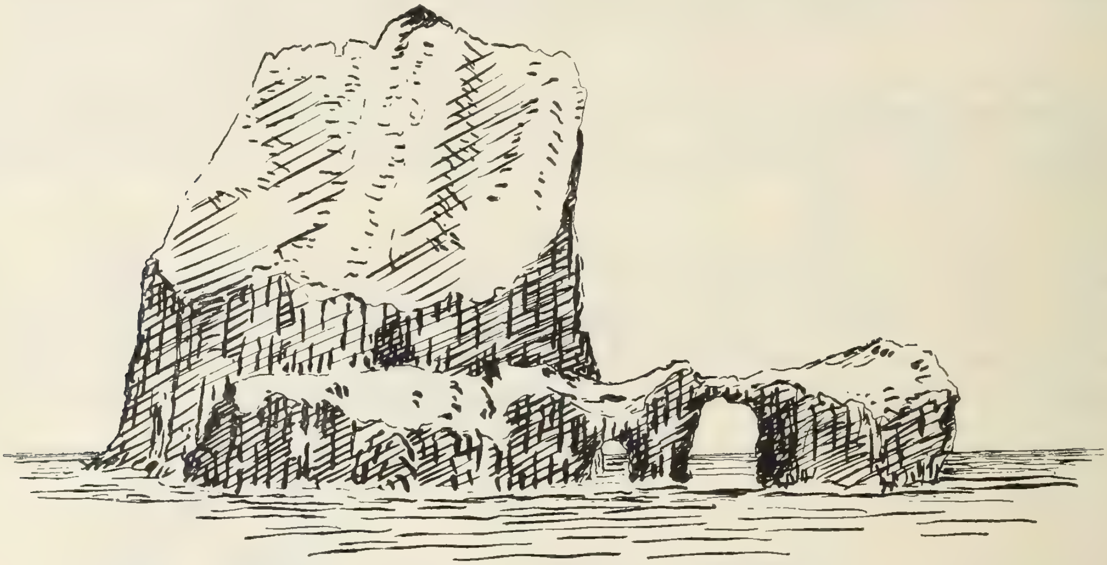

Fig. 9.—Islets in the Possession Islands Group. From the west. (After a sketch by Dr. E. A. Wilson.)

The island is comparatively flat on top, the highest part being a low dome towards the northern end. As far as it has been circumnavigated it everywhere presents a sheer face of cliff to the sea, except where the thick ice cap escapes and forms floating fans or tongues similar to, but smaller than, those of Sturge Island.

An ascent to the plateau of the island would be difficult at any place except up one of the cliff glaciers. On the west side, however, there may be accessible points particularly as there cannot be the same intensity of marine erosion on that side. A small penguin rookery has been reported on the north end near Cape Wadworth, but as the group of birds was seen in late January it is possible that they were there to moult and do not represent a rookery.

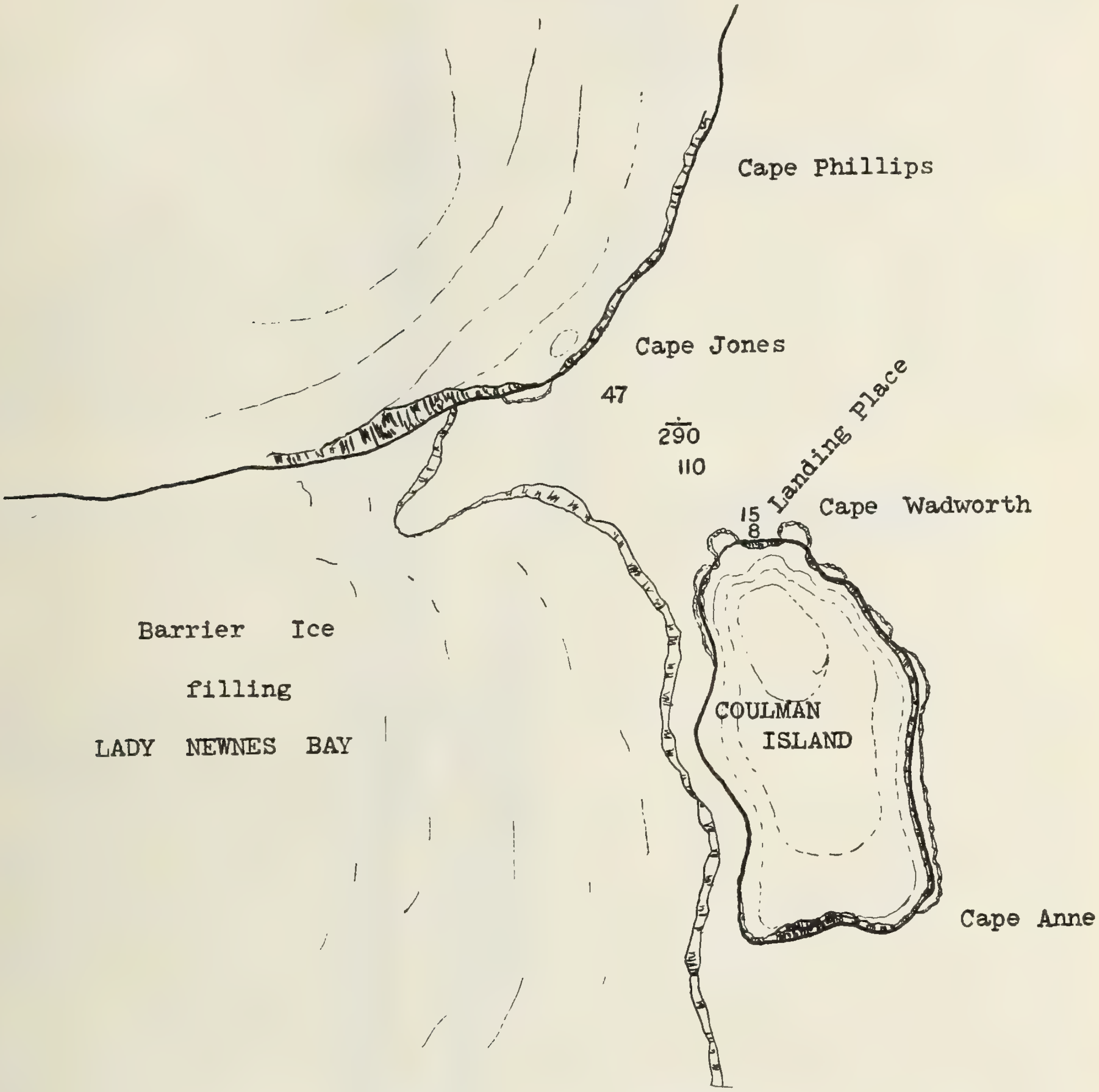

Fig. 10.—Sketch plan of Coulman Island and its environs. Scale approximately 8 miles to the inch.

The island is composed of basalts and light coloured tuffs, more or less level bedded, giving a stratified appearance to the cliffs. It is noteworthy that in the channel to the north the *Discovery* found that the compass was very much affected, probably owing to

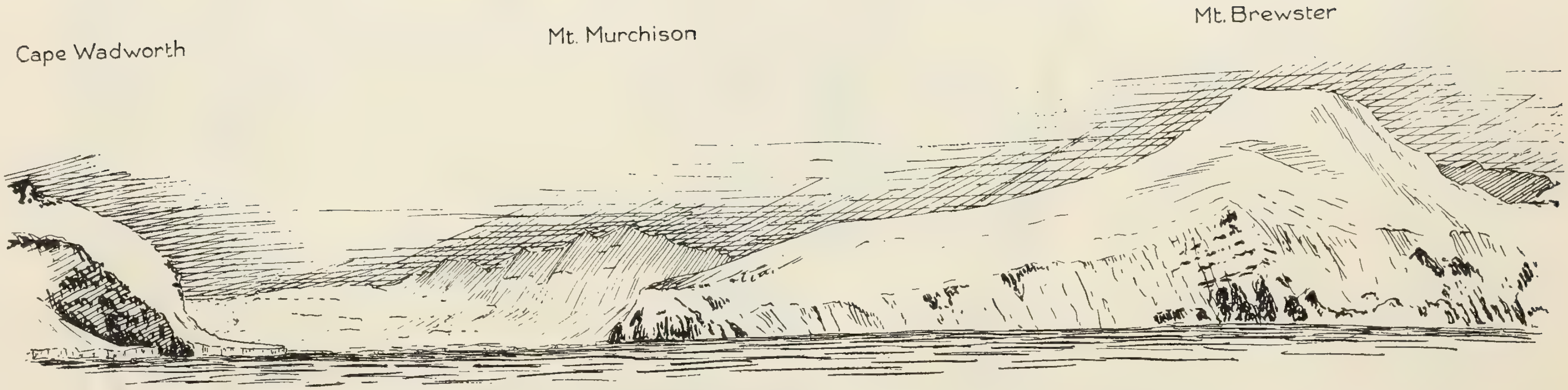

Fig. 11.—View looking south-west through the channel between Coulman Island and the mainland.

the very basic character of the lavas. The soundings in this channel are also somewhat remarkable and lead one to suspect that formerly the Newnes Barrier passed through the channel and deepened it to over 300 fathoms. (*See* Fig. 11.)

FRANKLIN ISLAND.

This small volcanic island is situated in Lat. 76° 07′ S. and Long. 168° 20′ E., and is therefore over 60 miles from the nearest land, though structurally it is connected with the Ross Island volcanic centre to the South and with Coulman Island to the North.

Discovered and named by Ross in 1841, it has since been visited by several expeditions, some of which have landed on the large beach on the south-west side without much difficulty. On the north-east side a landing was made by Ross on a steep-to rocky beach which cannot be recommended.*

The island is about 12 miles long and half as broad and its highest point is a black peak about 2,000 feet high. But the greater part of it is much lower and covered with a comparatively thin ice cap, which forms cliffs of ice on the north-west side. On the south-west side under massive cliffs up to 400 feet in height there is a very extensive beach, occupied in the summer by an immense rookery of Adelie penguins. (*See* Fig. 12.)

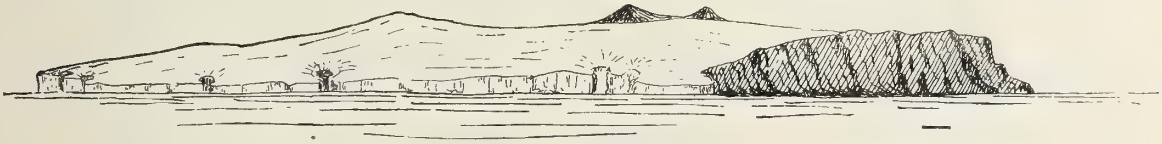
Beach and Penguin Rookery.

Fig. 12.—Franklin Island from the south-west.

The island tapers towards the south and from it extends a dangerous reef of rocks for 4 miles, called the Norway Rocks by Borchgrevink, with probably a deep water passage between them and the cape.

The island consists wholly of basic lavas and tuffs, very similar to those of the Hut Point peninsula of Ross Island. The island and the ridge from which it springs has the effect of diverting the drift of the ice to some extent, so that when one side of the island is densely packed the other is generally clear, and from the drift of the *Aurora* and the experiences of the *Terra Nova* it is apparent that the island forms a sort of pivot for the pack ice coming up from McMurdo Sound, which at this latitude tends to wheel round and pass in a north-easterly direction until it clears Coulman Island. According to Ross there is good holding ground near the shore on the north and north-west sides, the bottom being fine sand and stones, but it may be assumed that until the end of January at all events the island would seldom be quite clear of drifting ice.

DOUBTFUL ISLAND.

(75° 45′ S. 166° 10′ E.)

There can be little doubt that this island reported by Ross (as doubtful) in 1841 does not exist.

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* It was in attempting this landing that Hooker (afterwards Sir Joseph) nearly lost his life.

The vicinity of the assigned position was passed and repassed frequently by the *Terra Nova*, particularly in the 1911–12 season.

Unfortunately, the ice conditions, or the work the ship was engaged on at the time, never permitted a proper search to be made or a sounding to be taken on the exact spot, and the weather was thick on four days out of the six that the ship was closest. However, taken in conjunction with the tracks of the *Discovery* and *Southern Cross*, the evidence against its existence is fairly conclusive.

The courses of the *Terra Nova* with respect to the charted position are as follows :—

February 10, 1911.—Passed to the eastward of this position, 13′. The ship was fixed by Franklin Island when 22 miles off, and Mount Melbourne was seen some 90 miles off.

January 8, 1912.—Passed to the north-eastward distant 12′. Foggy but cleared later when still within 14′ to the northward of this position.

February 19, 1912.—To the eastward, 9′. Clear weather.

February 22, 1912.—To the northward, probably only some 2 or 3 miles, but snow restricted view to a few cables most of the time.

March 1, 1912.—To the westward, probably 3 miles, but snow restricted view very much at times.

March 6, 1912.—To the eastward 7 miles (approximately), snow.

BEAUFORT ISLAND.

This small island in Lat. 76° 58′ and Long. 166° 50′ E. was also discovered and named by Ross in 1841, and has some interest for the navigator since it tends to block the westward drift of the pack along the north side of Ross Island. It is about 1,600 feet high and has a peculiar appearance, being egg-shaped, completely covered with snow on the western side and almost completely bare of snow on the eastern side. The rocky side is very steep and denotes the heavy erosion that is common on the eastern sides of all the islands in the Ross Sea ; there is apparently no beach or landing place on this side. On the west a long ice slope terminates in a cliff from 5 to 50 feet in height and the island could be easily climbed from this side. It was visited by one of the sailors of the *Morning* in 1903 who landed on the Southern extremity, walking over dense pack ice to get to it,* but nothing is known of the island beyond its peculiar appearance and that it is volcanic. (*See* Figs. 13 and 14.)

The current in the passage between Cape Bird and the island sets to the west and is affected only in strength and not in direction by the tides. There does not seem to be much danger of heavy pressure in the pack as it passes through the channel, and several ships which have been held up in this passage have drifted through with the ice, being released as soon as Cape Bird itself was passed. The few soundings that are available near the island point to its being surrounded by deep water.

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* This feat was performed by a seaman named Paton, strictly against orders, and he signalised it by naming his next infant Beaufort. He himself lived to see the island once more from the decks of the *Terra Nova*.

Harbourage.

A few remarks on what is known of the shelter to ships which the coast affords may be of value.

It must be remembered that easterly and south-easterly weather is the rule in the Ross Sea, and the drift of the ice is due to that. But strong winds blow outwards from the plateau and must be reckoned with when close to the coast, although they do not seem to reach far out to sea.

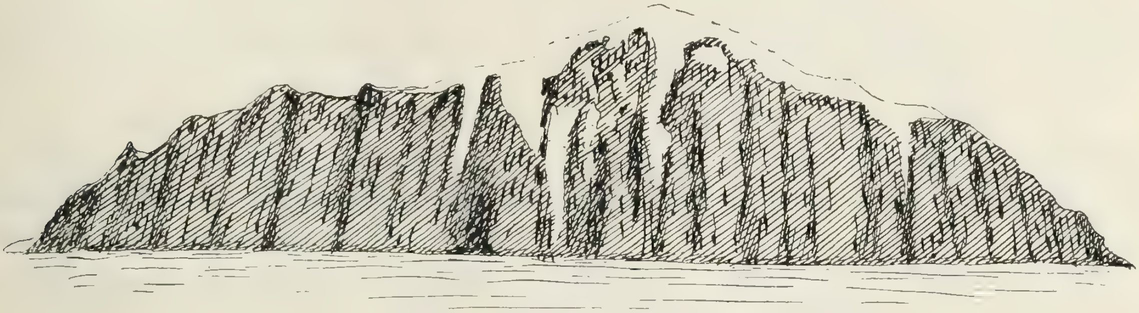

Fig. 13.—Beaufort Island from the east.

Beginning from the north, the first harbourage of any kind is in Robertson Bay, fully dealt with below (Map XIII).

The coast in the neighbourhood of Cape Cotter (Lat. 72° 30′ S.) is deeply indented. The survey at this point is far from accurate, and little is known about it, but it is significant that Scott in 1904 was very much impressed with these deep embayments and considered them well worth future examination. To reach them early in the season might be difficult on account of drifting pack, but by February the supply of ice from the South would be slackening, and the continual northerly set of the water would prevent any prolonged stagnation of the pack in the vicinity.

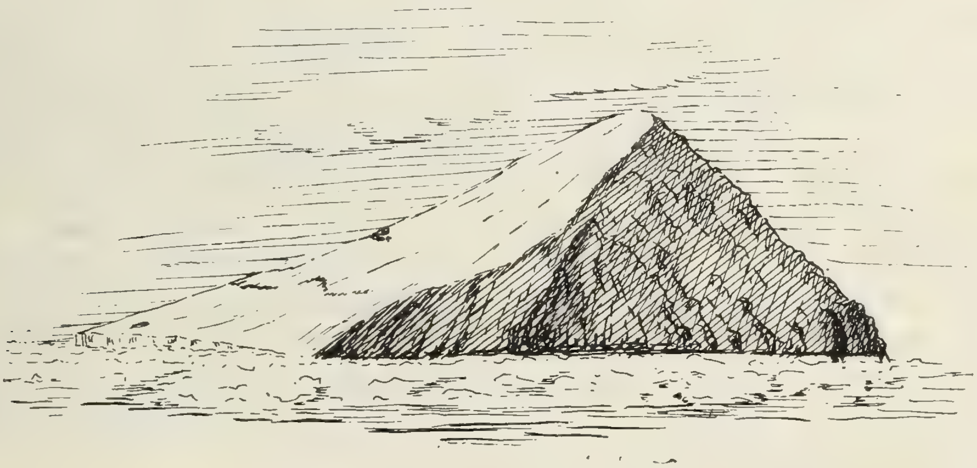

Fig. 14.—Beaufort Island from the south-west.

Similar reasoning applies to the inlet between Cape Jones and Coulman Island, which has been twice visited. The soundings are too deep for anchoring, but the barrier itself or the sea-ice in the small inlets should give fair holding to ice anchors. Compared to the open roadstead of Robertson Bay, this offers almost handsome shelter, and if whalers ever seek Ross Sea as a cruising ground, it would probably form a convenient rendezvous for the northern section of the industry.

The description by Borchgrevink of Wood Bay, the deep inlet to the north of Mount Melbourne, is a glowing one, there being at its head a shelving beach, good holding ground and shelter from westerly weather. On the other hand, attempts have since been made by the *Discovery* and *Terra Nova* to reach it, but each was blocked by close pack. The existence of an Adelie penguin rookery on the beach shows that the ice moves out fairly early in the season, but further reports would be required before recommending it, even if it were occasionally accessible.

To the South of Cape Washington there is another apparent shelter which was well reported upon, but has since proved untrustworthy. The long projection of the Drygalski Glacier Tongue holds up the pack-ice drifting up the coast, and the water in its lee is therefore generally clear of ice. But the pack edging round the end of the tongue packs tightly and prevents access, and probably egress, to any but the stoutest engined ship. In the three separate attempts of the *Terra Nova* to rescue Campbell's party in February, 1912, this dense and freezing ice was met, although the shore party saw nothing but open water from their look-out in Evans Coves.

The possible harbourage South of this point is dealt with in the description of Map IV.

Currents.

There is little that can be added in this connection to the data already on the map, the wavy arrows of which indicate always authenticated and determined directions and, where figured, an actual measurement ot rate.* The general course of the drifting pack is well shown by the course of drift of the *Aurora*, but this merely follows the outline of the coast, as one would expect, and does not greatly help to solve the more important problem of the position of ice-free water in Ross Sea at any part of the season. Even the observations available—and all that could be obtained are plotted on the map—are open to different interpretations and only a broad analysis is attempted here.

The straight lines on the map simply serve to connect the positions of entry into and exit from the pack of any one ship and naturally do not in the least represent even the mean of the courses. One or two of these are instructive at once. For instance, the very long slant of the *Southern Cross*, which holds the record for length of time in penetrating the pack, was obviously due to her general course which was opposed to that of the drifting pack instead of across it.

At the opposite extreme was the short passage of the *Nimrod* in 1909, when the flimsy pack she did meet with was passed in two days, and it is to be noted that her general course was nearly at right angles to that of the *Southern Cross*. There is no doubt, however, that the season was exceptional. Very close to the same meridian was the five-day passage of the *Erebus* and *Terror* in 1842, though that was a fortnight later in the season ; in fact, the *Nimrod* holds the record for an early passage into the open Ross Sea.

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* When laid up in the pack ice a ship can easily make relative measurements of drift by astronomical means; these must be compared with the records of a current meter sunk well below the ice before an absolute measurement can be obtained.

A more direct comparison of local conditions can be made for the years 1911–12, when both the *Fram* and the *Terra Nova* were negotiating the ice at about the same time. The former, in 1911, keeping to the west of what appears to be a critical meridian, met the pack one degree further south than the *Terra Nova* had done 24 days earlier, but took only four days to pass it as compared with 21 days by the other. On this passage the *Terra Nova* traversed many miles of rapidly wasting thin spring ice, which had evidently quite disappeared in the fortnight or so between the passages of the two ships.

In the next year the two ships both made a reasonably short passage, nine days for the *Fram* and twelve days for the *Terra Nova*, and again the more easterly ship met the most ice.

The passage of the *Terra Nova* in 1912–13 is of more than ordinary interest, as it was undertaken so far to the east in order to add to our knowledge of the easterly pack It was not met with until Lat. 69° 20′, a very high latitude, but it proved extraordinarily heavy, exactly as Ross had found it in the same neighbourhood in 1842.

No northward passages are plotted for the reason that no serious trouble with pack has ever been met with by ships returning in late summer. Even in 1913, when the *Terra Nova* was passing the pack zone at the end of January, an unusually early return, she met with none of any significance.

We may summarise very roughly by stating that the best approach is slightly to the west of the 180th meridian on a general S.S.W. course, and that no short passages can be expected if pack is encountered much before Christmas Day. It is also clear that the northern edge of the pack is more regular than the southern, doubtless because of the westerly drift which is met with about the latitude of 64°.

Finally, there is probably a clear passage into Ross Sea along the meridian mentioned after the end of January until the young autumn ice begins to drift up from the South, that is to say, about the beginning of April.

Of special note is the fact that the very heavy pack met by the *Terra Nova* in 1912–13 was no bar to her homeward passage on a more westerly course less than a fortnight later. Certainly the evidence as to a certain degree of stagnation of the ice on the eastern side of Ross Sea is accumulating.

OATES LAND.

This short strip of new coast-line was discovered by the *Terra Nova* in February, 1911.

The whole time the ship was near this coast the higher land was hidden in cloud with the single exception of the afternoon of February 22, when two high and distant peaks were seen (Peter Mountains), and also from the masthead on this day a glimpse was obtained of more high and apparently distant peaks considerably to the west of them. These last were not seen again at all.

With this exception, whenever the weather cleared sufficiently to see the coast only, the coast hills showed, and even these often had their peaks in cloud. It is, therefore, impossible to say what appearance the interior would have from the sea.

Bowers Hills are moderate-sized, snow-covered hills, the highest peak being Mount Bruce (2,800 feet). This range extends from Cape Williams nearly to Cape Cheetham, though this latter cape is actually formed by a pinnacled hill distinctly separated by a valley or col from Mount Bruce.

To the West of Cape Cheetham is a bay (Rennick Bay), estimated at about 10 miles across the entrance, but the farther shore was only seen indistinctly and distorted by mirage.

Lillie Glacier Tongue presented no special feature of note, though, as seen by the chart, it is of considerable size. The height at its extremity was made out as 126 feet, though as the ship could not approach nearer than 4 miles, this is only a very rough approximation.

From Rennick Bay to Cape Kinsey the land was not seen at all owing to snow.

Between Cape Kinsey and Archer Point the coast is rugged, running into the sea in steep points with glaciers in between and rising behind into a range of mountains (Wilson Hills).

Between Cape Kinsey and Drake Head lies an inlet (Davies Bay).

To the West of Archer Point a hilly coast line trends to the W.N.W., apparently of the same character as that already described.

MAP II.

THE GREAT ICE BARRIER AND KING EDWARD LAND.

Scale and Projection.

The scale of 1:1,000,000 is adopted in order to allow of ready reduction to the other scales used in this series and to allow of sufficient detail being shown at important points.

The projection is a simple conical with the parallel of 78° S. as standard. There are, therefore, no errors of scale in the important part of the map which can be as large as the probable errors of position.

Sources and Framework.

The framework of the map may be said to consist of two points only, Cape Crozier and Cape Colbeck, these having been fixed with greater precision than any of the intermediate points.

The position of Cape Crozier on the map is the mean of the determinations by the *Discovery* in 1902, being

Lat. 77° 29·2′ S. and Long. 169° 34·5′ E.

There is no very well defined point at Cape Crozier and there is an element of doubt as to which part was taken as the cape by the *Discovery*, so that no great accuracy can be claimed for this determination. In 1911 a turn in the cliff immediately east of the Knoll was taken as the cape.

The position of Cape Colbeck as given on the map was determined by three sun sights on February 2, 1911, the bearing and distance by range finder to the point being taken each time. The point being a cliff of ice, probably aground, there can be no real permanency, but the position of Point A (the ship's position) was then

Lat. 77° 04·3′ S. and Long. 158° 10·9′ W.

There is seen to be a slight discrepancy between the blue and black surveys at this point which may well be due to a slight recession of the ice cliff.

The survey in black between these two capes was made by the *Terra Nova* in January and February, 1911, and is based on the ship's positions fixed astronomically and the runs by patent log in between, corrected for drift where possible. In all, twenty-three positions were fixed in this way as a secondary framework, nine of them being in the vicinity of Discovery Inlet. The distance of the face of the Barrier abeam of the ship was taken at suitable intervals by means of the range finder and its height at the same time by the Stuart meter. The soundings were taken by a Lucas sounding machine.

The errors of chronometers were determined by travelling rates from errors ascertained at Cape Evans on January 14 and 15, and again on February 9, the longitude of Cape Evans being taken as 11 h. 5 m. 38 s. E., as determined by carriage of chronometers from New Zealand. There is, therefore, every reason to suppose that the survey is as accurate as the conditions would permit.

To give an idea of the reliability of the survey of the Barrier the following examples of methods used are given :—

(i) The western extreme point of Discovery Inlet was fixed from
9.22 a.m. position February 5 to be in 78° 18′ 7″ S. 171° 17′ 2″ W.
5.09 p.m. January 31 20′ 9″ 29′ 4″.

Proportioning values :
2 for 31st sights
1 for 5th sights gives 78° 20′ S. 171° 25′ W.

(ii) After leaving the Bay of Whales, the ship's position at 2 a.m., February 5, was deduced from :—

Working back from 9.22 a.m., February 5, gives 78° 23′ 1″ S. 168° 16′ W.
Working up from 11.45 p.m., February 3, gives 78° 25′ 167° 45′ 7″.

Proportioning values, 2 to the 1st and 1 to the 2nd of above gives position 78° 23′ 7″ S. 168° 06′ W.

(iii) 9.30 a.m., January 29 :—
Worked up from 5.30 a.m. position 78° 00′ 2″ S. 173° 57′ E.
Worked back from 1.36 p.m., 29th, gives 01′ 8″ 33′ 8″

9.30 a.m. Mean position 78° 01′ 173° 45′ 4″

Generally, good sets of sun sights at sea may be expected to give within 2 or 3 miles of the correct position, for sights taken during the night with low altitudes they cannot be considered reliable; such sights affecting this map are those taken at:—

2.11 a.m., January 31, Obs. Alt. 8° 21′.
8.50 p.m., January 31, Obs. Alt. 8° 41′.
10.47 p.m., January 31, Obs. Alt. 6° 00′.
8.06 p.m., February 2, Obs. Alt. 7° 05′.
8.28 p.m., February 3, Obs. Alt. 7° 40′.
11.45 p.m., February 3, Obs. Alt. 5° 32′.

Except in the last case, however, these sights have been used more as checks on previous (or later) fixes than as of reliability themselves.

The range finder distances may be considered perfectly reliable within the limits of the scale to which the chart is drawn, as the distances were kept as small as possible, and the range-finder was adjusted before and after.

The survey in blue, by the *Discovery*, in the same months of 1902, is taken from the maps of that expedition. Less is known of the precise methods and framework upon which it is constructed,but it may be presumed that similar care was taken since both expeditions were under the same leader. In that case the distance of the barrier-face from the ship was found by cross bearings and distance run, and the angular height was found by sextant.

The survey in red, by Ross in 1841, is printed for general comparison, but since he was in a sailing ship he could rarely approach the barrier closely and his heights for the face of the barrier are all much exaggerated. His position for Cape Crozier was Lat. 77° 25′ S. and Long. 169° 10′ E., giving a discrepancy of four minutes of Lat. and 20 minutes of Long. (equivalent to 5 statute miles) from the later determinations. On the other hand, there is some reason to suppose that Ross took as his Cape Crozier the junction between ice cliff and rock cliff immediately east of the large penguin rookery in which case the real discrepancy is trifling.

Former Surveys and Maps.

The Great Ice Barrier was discovered by Ross in 1841, and was visited again by him the following year. A survey was made under difficult conditions, the result being shown in red on the present map.

The next visit was not until 1900, when the *Southern Cross*, under Borchgrevink, sailed from Cape Crozier to Long. 165° E. and a landing was made for a few hours. No detailed survey was attempted and the outline given in the maps of the expedition differs so widely from that of the careful survey of two years later that it has been ignored in this account.

In 1902 Scott in the *Discovery* made a detailed survey of the Barrier face and discovered King Edward VII Land. The result of this survey is shown in blue on the map and is the sole source of our knowledge of the land east of Cape Colbeck.

In 1908 Shackleton in the *Nimrod* attempted to reach King Edward Land without success and visited various points of the Barrier face, finding changes from his former visit when an officer of the *Discovery*, but no survey was attempted.

In 1911 the *Terra Nova*, under Pennell, re-surveyed the edge as far as Cape Colbeck as shown in the black outline on the map. In the same year Amundsen built his winter quarters at " Framheim " in the Bay of Wales, and a small local survey was made of which the full details are not yet published. The next year a brief visit to the same place was made by an expedition from Japan, of which no details are available.

Discussion of the Different Surveys.

A glance at the map shows that the free edge of the Barrier varies in position, and it is in fact subject to a general northerly movement affecting the whole mass, also to a periodic recession caused by the seasonal breaking away of large slices giving rise to many of the tabular bergs to be met with in Ross Sea.

It is in order to gain information about these two opposing movements of the edge and so help to solve the problems of this remarkable natural feature that these careful surveys have been made. It seems advisable, therefore, to discuss the surveys from the point of view of what deductions may be safely made and to attempt to point out what may be usefully undertaken in the way of measurements by future expeditions.

The surface of the barrier has now been travelled over by many parties along two main routes towards the South, one from the Bay of Whales and the other from Ross Island, and these journeys have established the fact that the greater part of the Barrier is afloat and that the mean height is slightly under 200 feet above sea level.* Only two measurements of its rate of movement have been made, both at the same place, a depot flag about 10 miles from the end of Minna Bluff. These measurements give a rate of motion of about 600 yards in the year, but the position of the measurement, so close to land, is unfortunate.

The rate of movement is almost the most important fact required about the barrier, and as will be seen, the rates obtained by measurements of the terminal face give figures of a very different order.

The *Discovery* survey was made in the months of January and February, 1902, and that of the *Terra Nova* in the same months of 1911, so that the map represents the changes of exactly nine years. It would be almost impossible to discriminate between movements of recession and those of true forward motion were it not that there are several places in the barrier edge which are recognisable in both surveys.

The most important of these points is between the meridians of 169° and 172° W., being a deep inlet (Discovery Inlet) enclosed between the main barrier and a lobe of it to the north. It will be seen from the map that this feature has not only preserved its shape during the nine years, even in minor details, but it has not moved northwards for more than a mile in that time.

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* The height of the face of the Barrier is no guide to its real thickness since undercutting and subsidence reduce the height of the cliff face, and the " rolls " in the surface also produce wide variations of height at the edge.

Another key point which may be recognised is between the meridians of 159° and 160° W., where a shallow bay seems to have retained its shape but to have moved in a Westerly direction. In this case, however, the similarity of shape in both surveys is not marked enough to assume that no ice has broken away in the interval, but rather that the conditions causing the bay are more or less permanent.

A third point of great interest is the recess in the face of the barrier on the meridians of 163° and 164° W., and the history of the changes here is known to some extent. A similar recess is seen in Ross's survey though much farther to the North, but when the *Discovery* reached this meridian it had developed into a double inlet, consisting of a wide bay and a long narrow inlet, separated by a long promontory of ice. This promontory was almost cut off from the main barrier as far as the surface view was concerned by a long valley running from the narrow inlet (Balloon Bight) to the wide bay to the west. A balloon ascent was made at this point and a small sledge journey was made to a point 12 miles south of the inlet, both of which established the fact that there were a series of east and west valleys similar to the one forming the inlet. These valleys varied in width from half a mile to 3 miles and were at least 6 miles long, the bottom of the valleys were from 10 to 20 feet above sea level and the summits of the ridges from 110 to 180 feet.

In 1908 Shackleton in the *Nimrod* went to this point, intending to place his winter quarters there, and was much surprised to find that the central promontory had disappeared, leaving a wide bay, the Bay of Whales. In 1911 the visits of the *Fram* and the *Terra Nova* established the outlines of this bay, so that it is now the best known section of the Barrier face.

We may now turn our attention to the amount of forward movement which can be measured from the discrepancies of the two surveys. In Fig. 15 is given an enlargement of the two surveys in Discovery Inlet, the data being taken from the original log books of each expedition. It will be seen that the similarity of outline is very close indeed so that we may presume that very little change has taken place. The amount of forward movement shown is under one mile, but having regard to the difficulties of surveying when the variation changes so rapidly one is inclined to believe that the discrepancies shown may well represent no movement at all but merely errors of survey. In any case we shall be safe in affirming that at this point the Barrier is moving very little indeed, certainly less than 150 yards per annum.

But in other parts of the map the forward movement is very evident indeed. It is clear that where the 1911 edge is south of the 1902 edge we can make no measurement but merely state that recession has been dominant. On the other hand, where the 1911 edge is to the north we can say that the difference represents a minimum movement forward for the nine years. In this way we can at least arrive at some approximate data as to the rates of movement. The question as to how much is to be allowed for the errors of survey can only be settled in an arbitrary way, but it seems that an allowance of 1 statute mile should be sufficient, that is to say, we may trust the minimum rates derived in this way to the extent of 200 yards per annum.

The following table shows the movements on various meridians obtained from measurement made in this way, and it at once leads to the conclusion that the rate of motion found near Minna Bluff was only local and that the open Barrier is moving very much faster. The variations in rate of motion given by the table are, of course, not real in every case, for no account of the recession by breaking away can be made and we can only derive minimum rates from the surveys. On the other hand it would be obviously wrong to deduce that the rate is everywhere the same.

Table of Minimum Movement of the Barrier Edge.—Years 1902–11.

Meridian.	Minimum Movement.	Minimum Rate.	Average Height of Edge. 1911 Survey.
	Miles.	Yards per Annum.	Feet.
Cape Crozier.	0·5	100	60
170° E.	1·0	200	70
171	5·0	1000	70
172	4·0	800	80
173	0	—	140
174	0	—	120
175	1·0	200	60
176	0	—	65
177	2·0	400	60
178	3·0	600	30
179	7·0	1400	25
180	6·0	1200	20
179° W.	6·0	1200	80
178	7·0	1400	80
177	6·0	1200	65
176	7·0	1400	60
175	10·0	2000	80
174	9·0	1800	75
173	6·0	1200	60
172	4·0	800	60
171	2·0	400	—
170	1·0	200	Discovery Inlet.
169	1·0	200	
168	Recession 1·0 miles.		—
167	Recession 3·0 ,,		—
166	Recession 3·0 ,,		—
165	—	—	—
164	Recession probable		—
163	Recession 3·0 miles		—
162	Recession 1·0 ,,		—
161	4·0	800	140
160	8·0	1600	150
159	7·0	1400	90

The most conclusive figures are in the stretch between the meridians of 180° and 170° W.

Over this distance the *Terra Nova* survey has no less than 14 positions fixed astronomically and the *Discovery* passed over the eastern half of it twice over. It is here that we get the highest rate of motion, which is a somewhat surprising figure, about one mile in the year, three times the rate at Minna Bluff. The direction of the motion is not necessarily the same all along the face of the Barrier, but for the purposes of the table the measurements have been made in a direction normal to the face in each case.

Another minimum measurement of forward movement in the same period has been arrived at from a comparison of photographs of the junction of the Barrier with the cliffs at Cape Crozier, and as shown in the inset map amounts to about half a mile. (*See* Fig. 16.) The figure means very little, however, since from the changed face there has obviously been considerable recession at work at this point, and the rate of movement in any case would not be representative in such a place.

Just as surprising at first sight as the high rate of motion is the fact that the Discovery Inlet lobe is practically stationary. The soundings show that it cannot be aground anywhere near the edge but there is, obviously, an obstruction to the movement in the neighbourhood. From a study of the ice of the inlet itself (*see* Fig. 17), showing the presence of east-west valleys and ridges very similar to those of the Bay of Whales region, one is led to suspect a similar cause, that is to say the existence of land checking the Barrier somewhere to the south of the lobe and to the east of the 170th meridian. It could hardly be extensive land since the *Discovery* observed a strong current from the South-east while in the inlet.

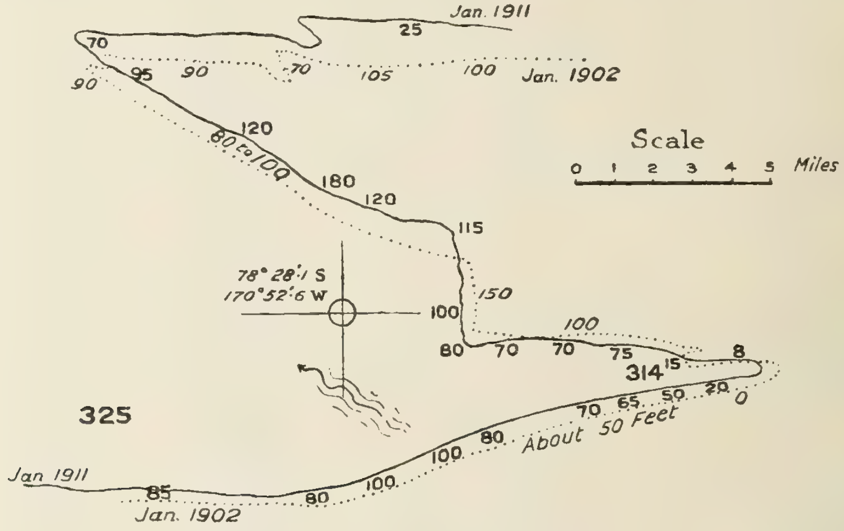

Fig. 15.—Plan of Discovery Inlet.

The obstruction to the south and east of the Bay of Whales is not extensive, and the Barrier proper, that is to say the level uncrevassed surface, continues to the east of it, as observed by one of Amundsen's sledge parties. But between the Bay of Whales and King Edward Land its direction of motion certainly changes as one would expect, becoming more westward as one goes east.

The *Terra Nova* survey is incomplete on this section, but there is enough to show that there has been considerable movement forward, and the rate of motion must be

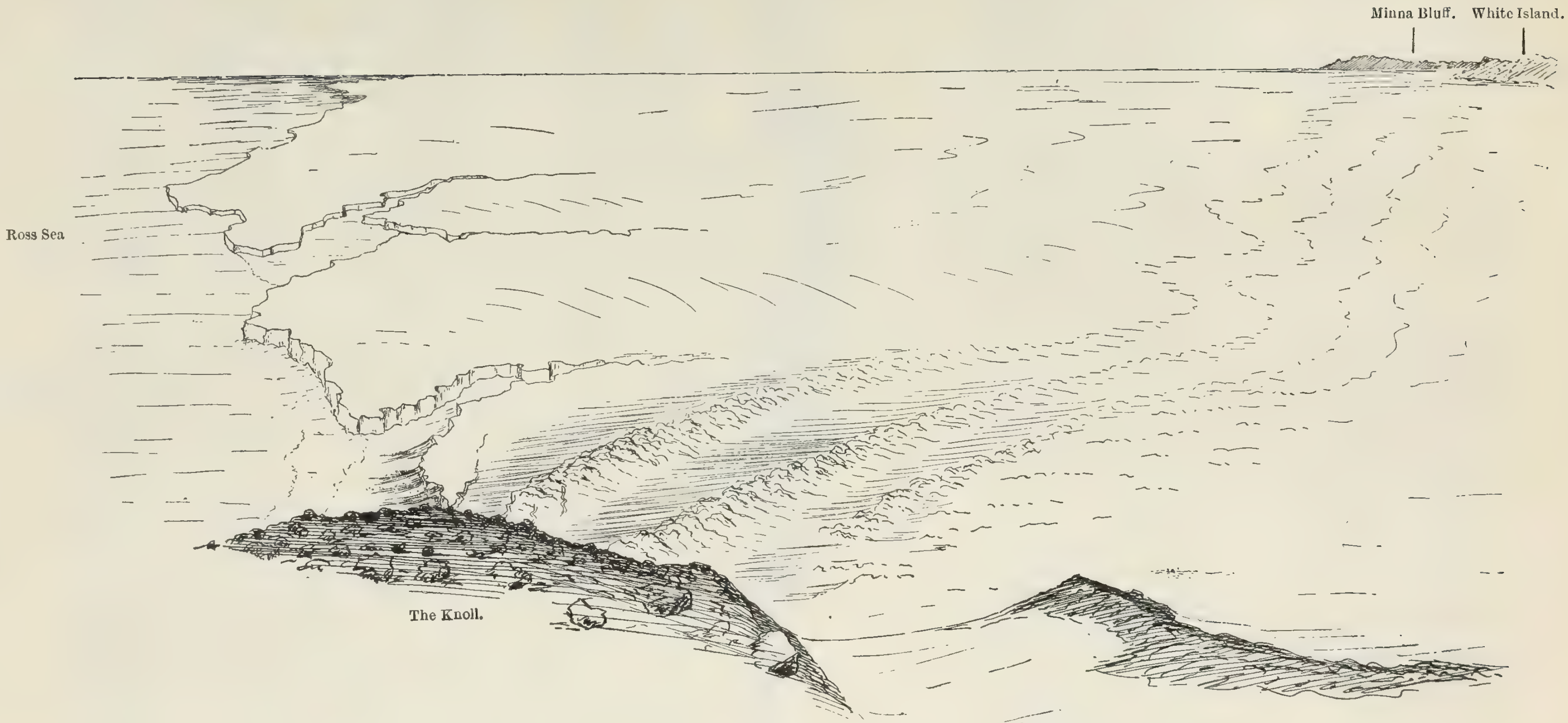
Minna Bluff.
White Island.
Ross Sea
The Knoll.

Fig. 16.—Junction of the Barrier and Ross Island at Cape Crozier in 1902. (After sketches by Dr. E. A. Wilson.)

high. But from the evidence of the soundings it is clear that the floating Barrier must come to an end somewhere near the 158th meridian, the remainder of the ice cliff being but a short distance out from the undulating slopes of King Edward Land. The two surveys agree almost exactly here, due not to lack of movement but probably to the fact that the ice coming off the steep slopes is already fractured when it reaches the sea and is, therefore, readily detached and removed by the swell and the easterly winds.

KING EDWARD VII LAND.

At least four ships have attempted to get to the east of the Ross Barrier, but of these none but the *Discovery* in 1902 has had any real measure of success, the way being stopped in all other cases by heavy and close pack. The data here collected about this region come from the reports of the various expeditions and are given for the purpose of stating the difficulties more clearly than has yet been attempted and describing the features more fully. The map of this region is taken from Mulock's charts, but with additions from the original records. The gradual discovery of King Edward Land is well described by Scott in his 'Voyage of the *Discovery*,' but the absence of bare rock on its Western side made it difficult to say where the land really began until the sledge party under Prestrud fixed it in 1911.

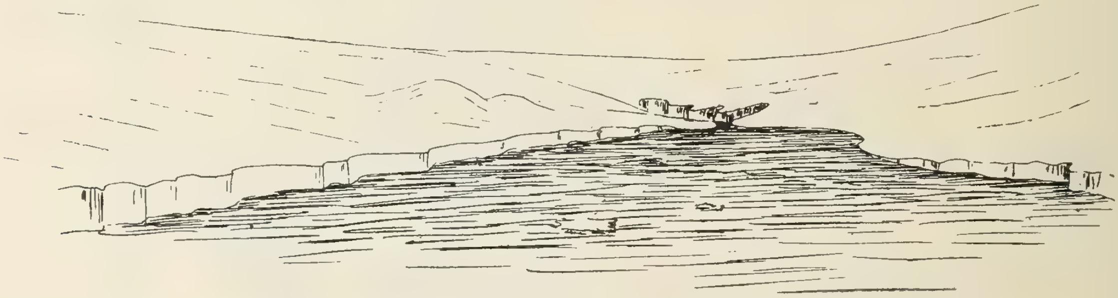

Fig. 17.—Sketch of the end of Discovery Inlet. Looking east. (From data of the *Discovery* Survey, January, 1902.)

The exact position of their descent to the sea ice is not given in the narrative, but from the description in the text it appears to be the deep bay in Lat. 77° 40′ and Long. 159° 30′ W. Here they took a sounding of 130 fathoms and on proceeding to the north-east they found the ice beginning to slope up, attaining a height of 1,000 feet after twenty miles travel. These observations exactly agree with those from the decks of the *Discovery*, but on account of the poor visibility they were not considered indubitable evidence of land at the time.

Ships attempting to reach Cape Colbeck have always met with a great deal of heavy pack, the *Discovery* in 1902 also having the same experience, but keeping close to the Barrier found a comparatively narrow channel which remained moderately free. They made an important observation in this connection in finding that south of Cape Colbeck there is a south-westerly current running up to two knots, and it is this which brings down the heavy pack from Biscoe Bay. All accounts back to that of Ross agree in characterising the pack-ice of the eastern side of Ross Sea as particularly heavy.

Biscoe Bay itself presents several remarkable features. It is apparent from the soundings as well as from vague indications of distant mountains that the trend of the coast is towards the North-east and that for at least 80 miles the coast is fringed by a peculiar formation of ice, a sheet something between sea ice and barrier ice. Closer to Cape Colbeck there were in 1902 two sheets, a high one inshore and a low one to seaward, whose junction was clearly visible from the ship.

This observation tends to convince one that the lower sheet is sea ice some years old, while the higher is the true land ice. The retention of the sea ice is aided by the presence of the peculiar " ice islands " of which Fig. 18 is an example. For the most part very high, up to 250 feet, these ice masses were uniformly domed and some were of great extent, one being 8 miles long. The soundings taken quite close to them, one at two cables length, show that the masses are certainly aground. But since an iceberg when aground becomes lighter by loss from above and either breaks up or floats away, it is clear that they cannot be mere icebergs but that they have grown in situ. It seems probable that they are the ice caps of small islets and are therefore semi-permanent. The low ice behind these masses was in each case pressed up against them by the motion of the land ice behind. The evidence for a very heavy snowfall in this region is overwhelming.

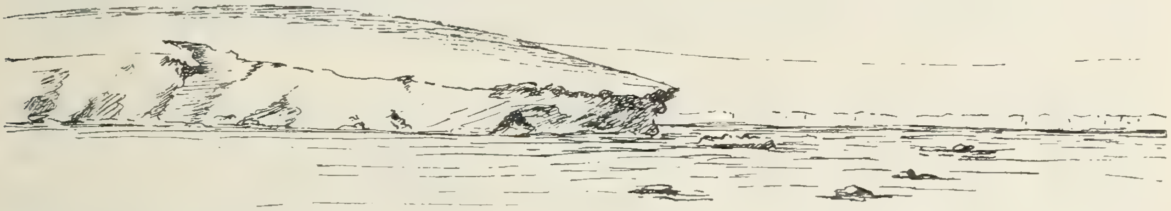

Fig. 18.—An " Ice Island " off King Edward VII Land in Longitude 156° 30′ West; height, 200 feet. Sounding from where the sketch was taken, 100 fathoms. (After a sketch by Dr. E. A. Wilson, made on January 30th, 1902.)

It is of importance to note that when the *Discovery* had reached her farthest point in Biscoe Bay the way to the East was barred by an immense sheet of sea ice quite smooth and showing no sign of pressure, though held in by icebergs and ice islands, and that it showed many sodden patches, signs of currents passing over shoals and also of an imminent break up of the sheet. This was on January 31, and it therefore seems probable that the way to the East may be open late in the season. An appearance of land to the E.N.E. was seen at this point but no very definite form was revealed, so that although the same appearance was seen next day doubt has been cast upon its existence. One can at least say that the indications are that the coast of King Edward Land trends in a general E.N.E. direction, that it has shallow soundings and small islets off it, a heavy snowfall and that it is usually protected by heavy pack-ice which drifts towards the West very slowly. The land seen is comparatively low, up to 3,000 feet and mostly snow covered. The journey of Prestrud has proved that it is continental in type, but the same journey leads one to believe that the floating barrier extends to the South of it, and that it is isolated at all events from the " appearance of land " seen by Amundsen in Lat. 81° 30′.

The *Terra Nova* succeeded in rounding Cape Colbeck in 1911, and found that the low cliff had receded somewhat from the 1902 position, but the ship was prevented by thick pack from proceeding farther so that the later history of the curious ice islands of 1902 is not known.

One may sum up the experiences of the past by saying that probably the best route towards the East here is close to the land where there is often a narrow strip of clear water, that the best time would be in mid-February, but that there would be some risk in penetrating far at such a date on account of the heavy ice and evidences of pressure to be seen there.

Currents and Movements of Ice.

The little that is known of the surface currents appears on the map, and shows that the prevalent easterly winds have a very definite effect on the surface water, which is only modified in rate and not altered in direction by the tides. Over 50 per cent. of the high winds at the Bay of Whales are from the east and it is for this reason that the whole of the ice movements in the southern portion of the Ross Sea have a westerly trend. Towards Cape Crozier the prevalent wind is much more southerly which gives the key to the movements of the ice. Heavy or stagnant pack is rarely met with along the western third of the Barrier face, and in the case of each expedition few icebergs were met with until after passing the 180th meridian going east. This is due to the general north-westerly movement of the water here.

The surface current has been logged up to 3 knots but varies in strength according to the tides and previous weather. That it is only a surface current is proved by the behaviour of a certain iceberg met by the *Discovery* in 1902 on her way east and again twelve days later on returning. It had drifted 70 miles to the westward in the interval, a much smaller distance than surface ice would have gone in that time.

It seems probable that the southern part of Ross Sea, close to the Barrier, is kept free from permanent ice throughout the year by these winds and currents. A water sky was constantly seen from Framheim in the direction of the sea, the ice remaining only in the shelter of the Bay of Whales.

Soundings and Landing Places.

The soundings inserted on the map are derived from all the sources available, including a large number taken by the *Terra Nova* in 1911. They are naturally of particular importance near the face of the Barrier and as is well known have quite established the fact that it is afloat for the greater part of its extent. The bottom of Ross Sea is remarkably uniform in depth in this region with a slight rise towards the east from the deeper water, averaging 400 fathoms, near the volcanic belt of Ross Island, Beaufort and Franklin Islands.

The depth required to float a typical Barrier berg is not yet established. The upper part of such a berg is of small density, but on the other hand it increases rapidly below the water line. It seems that the ratio of ice above and below the water line may occasionally be as high as one to five, but possibly a more usual figure would be one to six.

The suggestion has been made that the uniform depth of the Ross Sea has some connection with the former extension of the Barrier itself. The average depth over a great part of the Southern Ross Sea is 300 fathoms, and this would demand a height above sea level of 300 feet of the cliff edge in order to allow of a planing action of the sea floor. This is by no means excessive as the average height of the Barrier away from the sea is even now about 170 feet, and the *Discovery* passed close to one piece near King Edward Land which was 280 feet in height.

The bottom samples are mostly of soft mud with occasional erratics dropped by bergs and land ice. A dredging in the Bay of Whales brought up a large amount of mud and small rocks, the latter being nearly all gneisses and other continental rocks.

As will be seen from the map there are several places along the edge of the Barrier where the cliff face is low enough to permit of a landing from a ship. The most favourable of these are in the Bay of Whales and in Discovery Inlet, both of these being sheltered places for a ship to lie, from which a short journey might be made to investigate the Barrier surface towards the south. But there are in addition a large number of small inlets, too small in general to appear on the map, where the surface comes almost to sea level, and there is also a long stretch of low edge from the meridian of 177° E. to 180°.* In Biscoe Bay the ice sheet is almost everywhere low enough to permit of a landing.

MAP III.

THE SOUTHERN JOURNEY.

Scale 1 : 1,000,000. Projection : Polar Equidistant.

This map has been constructed to illustrate the route to the Pole originally discovered by Shackleton in 1908 and followed by Scott in 1911–12. Being on a polar equidistant projection, all measurements along the meridians are true to scale, and the distortion along the parallels is negligible in the small lateral extension of the map.

Sources and Framework.

The map is a compilation from the excellent surveys of Scott and Mulock in 1903 which reach the latitude of 83 S., from the surveys of Marshall of Shackleton's party, and from those of Evans and his helpers on the Southern Journey of 1911–12. All of these were made under similar conditions, and were practically sledgemeter and compass traverses, checked by sun observations.

The framework, if it may be so called, is the series of astronomical positions determined en route by Evans. These were all re-worked, checked and mean values calculated by Rennick in 1914, leaving only the detailed drawing to be done by the writer.

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* From the experiences of the *Terra Nova* and the *Fram* it seems probable that these inlets in the Barrier will form very suitable centres of rendezvous for whaling, especially such an ice-locked harbour as Discovery Inlet.

Therefore, as far as latitude determinations are concerned, there can be no very serious errors. The probable error of an altitude sight with the theodolites used is less than one minute, which is equivalent to about one-thirtieth of an inch on the scale of the map.

The meridians, however, may be considerably in error, owing to the unknown behaviour of the chronometer watches, as described above. However, as most of the surveying was done on the outward journey within ten weeks from the time of rating, the errors should not be unreasonable.

The heights along the route are from aneroid and hypsometer readings, suitably corrected. Those of the mountain peaks are from theodolite altitudes and their accuracy depends on the proximity of the mountain to the route. The contours at 1,000 feet interval are interpolated on these with the aid of sketches and photographs and are to be regarded only as a general guide to the land forms.

To keep the northern part of the map in harmony with the rest the contours had to be drawn from the admirable sketches made of that part of the coast by Dr. Wilson in 1902. Acknowledgment is due also to the original field notes of Mulock and Barne, which were often consulted.

The pioneer survey of the Beardmore Glacier by Dr. Marshall in 1908 was naturally of the greatest assistance, and although considerable alterations from his map have been made in places, this has only been done where the more recent figures were so complete as to outweigh the earlier ones.

Some difficulty was found, both on the journey itself and in mapping from photographs, in identifying the names and features of the Shackleton map. One or two additional names have been given where required.

The Route.

The route has been plotted accurately and not conventionally from the framework of positions. On the Beardmore Glacier, however, it had to be generalised, numerous deviations being necessary which could not be surveyed even had there been time.

An attempt has been made to record some of the features of the routes, not usually shown on such maps. For instance, the direction of the dominant sastrugi or wind ridges in the snow has been plotted from the observations of Bowers, entered in his meteorological log, and from some notes on Barrier surfaces by Wright. The comparative intensity of the sastrugi has been shown roughly by varying the length of the arrow. Crossed arrows represent two distinct directions. On the Barrier these directions have been checked by the reports of other parties passing points at different times in the summer and may, therefore, be said to truly represent the directions of prevalent summer winds. On the plateau summit they represent the records of the out and home journey of one party only, but Bowers was an acute observer of this particular phenomenon, and the directions are probably true for the midsummer months. Special zones of strong winds from special directions may be recognised, and of particular interest are the small sastrugi at the Pole itself coming from the South-west (meridian 160 E.). The changes from any prevalent direction to another are preceded in each case by a belt of crossed or indefinite sastrugi.

The scale is too small to plot individual ice disturbances, though some of these were recorded, but the areas of crevassed ice are shown with some degree of accuracy, especially on the inset map of the Beardmore Glacier.

The undulations in the surface are also plotted conventionally as to number but fairly correctly as to extent and show the widespread disturbance of the Barrier surface where the outlet glaciers from the plateau debouch upon it.

The average height of the Barrier surface is given as 170 feet, which is the deduced height from the aneroid readings carefully corrected by Dr. G. C. Simpson in his memoir on the meteorology of the expedition. By no other means of measurement, short of levelling, can the height of such a remarkable feature be obtained, though the figure is of great importance from the point of view of the origin and movement of the Barrier. It is here suggested that a small hand-level should form part of the equipment of any party investigating the Barrier in future, especially near the land, where chasms, possibly to sea-level, were found by Scott in 1903. With such an instrument, weighing but a few ounces, and a couple of painted bamboos, lines of levelling could be run almost at marching pace with a probable error of less than one foot per mile.

Of special interest is the inset map of the Beardmore Glacier, by far the largest glacier yet traversed, but, as explained above, no great reliance is to be placed on its accuracy.

On such a glacier the only rapid and efficient method of surveying detail would be with a plane table, all methods involving reliance on sledgemeter distances or astronomical observations being unwieldy in comparison. An immense amount of trouble was taken with the observations as far as the need for haste would permit, and the map, unsatisfactory as it is on the whole, certainly represents the expenditure of much effort. Considerable care has been taken with the contour lines on the glacier to represent truly the gradients, and from the point of view of glaciology the map is possibly accurate enough. For any future party adventuring the glacier it is suggested that the route plotted is probably the best, but that bearings and courses taken from the map may not represent the route in nature. In addition, they are urged to take a small panorama camera with levelling attachments and a plane table as their chief equipment for survey.

MAP IV.

McMURDO SOUND REGION.

Scale: 1 : 500,000. Projection: Conical with standard parallel of 77° 30′ S.

This map is designed to show on one sheet the whole of the McMurdo Sound Region, which is perhaps the best known and mapped region of the continent. Most of the districts shown on the map appear on a large scale in this series, so nothing beyond the general features of the region will be dealt with in this account.

Sources and Framework.

The map is compiled from various sources, the immediate ones being Maps, V, VI, VII, VIII, IX, X and XI of this series, the method of survey of each district being described under its own map heading. For certain parts, notably the Upper Ferrar Glacier, the maps of the *Discovery* Expedition have been used, the actual surveys there being carried out by Armitage and Ferrar.

The map also includes one special survey not elsewhere described. This was the traversing of the northern coast of Ross Island from the *Terra Nova* when running from Cape Crozier to Cape Bird, the course being shown roughly by the line of soundings. Owing to the number of officers available at the time, the traverse was carried out as thoroughly as could be done without landing or having special marks. The bearings taken with the standard compass were checked by many sun azimuths, the range-finder was in constant use for close detail, vertical angles were taken with a separate sextant, the patent log was checked, and special sketches were made. But since the coast here consists mostly of ice-cliffs, the survey has no special interest of its own and is not reproduced separately. It will be noted that the outline of the coast departs considerably from that of former maps and in this case should supersede them. The depth of the deep bay opposite Mount Erebus, which was not entered, prevented accurate intersections, and therefore its coastline cannot be considered accurate.

From Cape Bird to Cape Royds a ship traverse for the coastline was made on a subsequent occasion but is not used, as a plane table survey from the slopes of Erebus proved more accurate.

The south side of Ross Island would be difficult to survey under any conditions, since the Ross Island ice here meets the Barrier more or less continuously. The dotted outline here used is founded on that of the *Discovery* maps with certain corrections made from data supplied by photographs and Wilson's winter journey.

As to the framework of the map, it is necessary to speak very frankly. There is no framework in the surveying sense of the term, and the control generally is lamentably absent, it is, in fact, a compilation with all the defects of such a method of constructing a map ; that is to say, the local detail (where in firm line) will probably be found fairly accurate, but the relative positions of the leading features may be found to be seriously incorrect. This arises partly from the illness and absence during the second year of the head of the survey organisation, but more directly from the fact that the original work and maps were assumed to be better than they really were.

The survey work of the *Discovery* Expedition was excellent as to the ground covered, and, in those parts specially supervised by Lieutenant Mulock, was as good as could be done under the circumstances, but a triangulation taking in the leading features could not be made, and the maps published were compilations only.

It must be realised, therefore, by any future expeditions which may visit the area, that nothing but a triangulation *de novo* will really put the matter right. This can be said without prejudice, since the region is admirably suited to triangulation methods, and, even though it were only carried out sufficiently to give a ten or twenty mile base on Ross Island, the theodolite intersections from that base for the principal peaks of the Western coast would give a result far more trustworthy than the present map.

It is an ever recurring complaint in exploratory surveying that the last man's work was " wrong," and sting is usually added to the complaint from the fact that the complainant has trusted it too much at first and wasted time in consequence. Such complaints, besides being generally unfair to the pioneer, will always recoil upon the complainant's head in time, for no survey work is beyond correction. The only solution of the difficulty is to publish no map without some explanation of its accuracy and method of construction, and, indeed, that is the chief reason for the issue of this memoir, to warn the future of the faults of the past.

There being no network of control which could be used for the map, it was necessary to build up on the best available points, and the following table shows those which have been used, together with their source. The probable error of each point could not be evaluated, and, in view of the fact that nearly all are by astronomical fix, it would not be of any real value :—

Cape Evans	By astronomical means. (*See* Chapter III.) (*Terra Nova* Expedition.)
Hut Point	Ditto. (*Discovery* Expedition.)
Cape Roberts ..	By sextant and carriage of chronometers from Cape Evans. (*Terra Nova* Expedition.)
Mount Lister ..	By intersections from a base in the vicinity of Hut Point. (*Discovery* Expedition.)
Mount Discovery ..	

To these points have been fitted the surveys mentioned above, and, in addition, a great deal of detail has been plotted by using the photographs taken on sledge journeys and even topographic sketches.

An attempt to give some idea of the comparative accuracy of different portions of the map is made in the form of a skeleton diagram in the corner of the map, which distinguishes those areas actually visited and surveyed on the ground from those surveyed by distant intersections and the still more doubtful areas plotted from sketches or other inadequate data.

A further measure of comparative accuracy is given by drawing the detail, which is reasonably trustworthy, in firm line and dotting that which is doubtful. It is hoped that by such means future parties will see where fresh work is needed, and some at least of their wrath be averted.

The method of contouring at 250 foot interval and distinguishing rock from ice slopes has been adopted in spite of the inaccuracy of many of the altitudes, since the map is intended for the use of students of land and ice-forms even more than for the guidance of future sledge-parties. The heights of the main peaks of the Western Mountains have been taken in most cases from the surveys of the *Discovery* Expedition.

The former maps covering all or part of this region are those of the *Discovery* Expedition, with a small scale map published by the *Nimrod* Expedition. The first were based on careful work in the vicinity of Hut Point of which no full account is obtainable. The mainland, however, was surveyed by a series of traverses without firm control on the pioneer sledge journeys up the Blue and the Ferrar Glaciers. For the most part the differences between that map and the present one will be found to be in matters of detail only, though new ground was covered towards Granite Harbour. The *Nimrod* map corrected some grave discrepancies in the vicinity of Granite Harbour, but elsewhere is practically a copy of the *Discovery* map.

Routes.

The only routes which call for remark on this sheet are those connected with crossing the Sound, passing up the coast, or reaching the Plateau.

As far as the Plateau is concerned, the pioneer route is still the only one attempted, up the Ferrar Glacier, full descriptions of which are to be found in 'The Voyage of the *Discovery*.' An apparently possible alternative is up the Mackay Glacier, keeping to the southern side to avoid the continuous ice-falls at 3,500 feet. Indications of nunataks were seen far beyond the ice-falls, and there is probably disturbed ice in their vicinity, but the gradient to the main level of the plateau must be much lower than in the Upper Ferrar.

A route up the Koettlitz Glacier would also be feasible, but a great deal of rough ice has first to be surmounted on the lower levels.

The routes for crossing the Sound must be of more general interest, since there are now three separate huts on Ross Island, and whichever side of the Sound is chosen by future expeditions for their headquarters site, crossings will be frequent. How fickle the ice in the Sound may be, even in winter, can be seen from the fact that in September, 1911, a party under Scott crossed on a straight line from Spike Cape to Cape Evans and withstood a heavy blizzard when half-way across. At the same time next year there was open water within a mile or two of Cape Evans, and, judging from later observation, the ice on the other side of the Sound was periodically blowing out.

The ice-chart of the Sound (Fig. 19) is an attempt to plot the observed positions of the ice at special seasons and also emphasises the great variation from year to year.

The experience of past expeditions may be summarised as follows. It is more than probable that the Ross Sea is never frozen over for more than a few days at a time, and this condition seems to reach as far as a line drawn north-westerly from the bare land of Cape Bird to within some 15 or 20 miles of the mainland coast. The line, however, will vary widely in different seasons as shown in the chart, occasionally coming down as far as a curve southwards from Cape Evans round to Blue Glacier. The safety of spring crossings of the Sound, therefore, depends entirely on the permanence of the ice in the Sound from June onwards, and a route that is safe in September will probably remain so until early in December. At that time the summer break-up begins.

The positions of the penguin rookeries are some guide as to the average ice conditions. They arrive from the north in early October, and though content to walk even ten or fifteen miles over the ice to reach the rookery to begin with, they require open water in the vicinity by the beginning or middle of November. Now on the eastern side of the Sound, the most southerly rookery is at Cape Royds, while on the western side there are none at all, in fact, the most southerly one recorded is in Evans Coves (Lat. 75° S.).

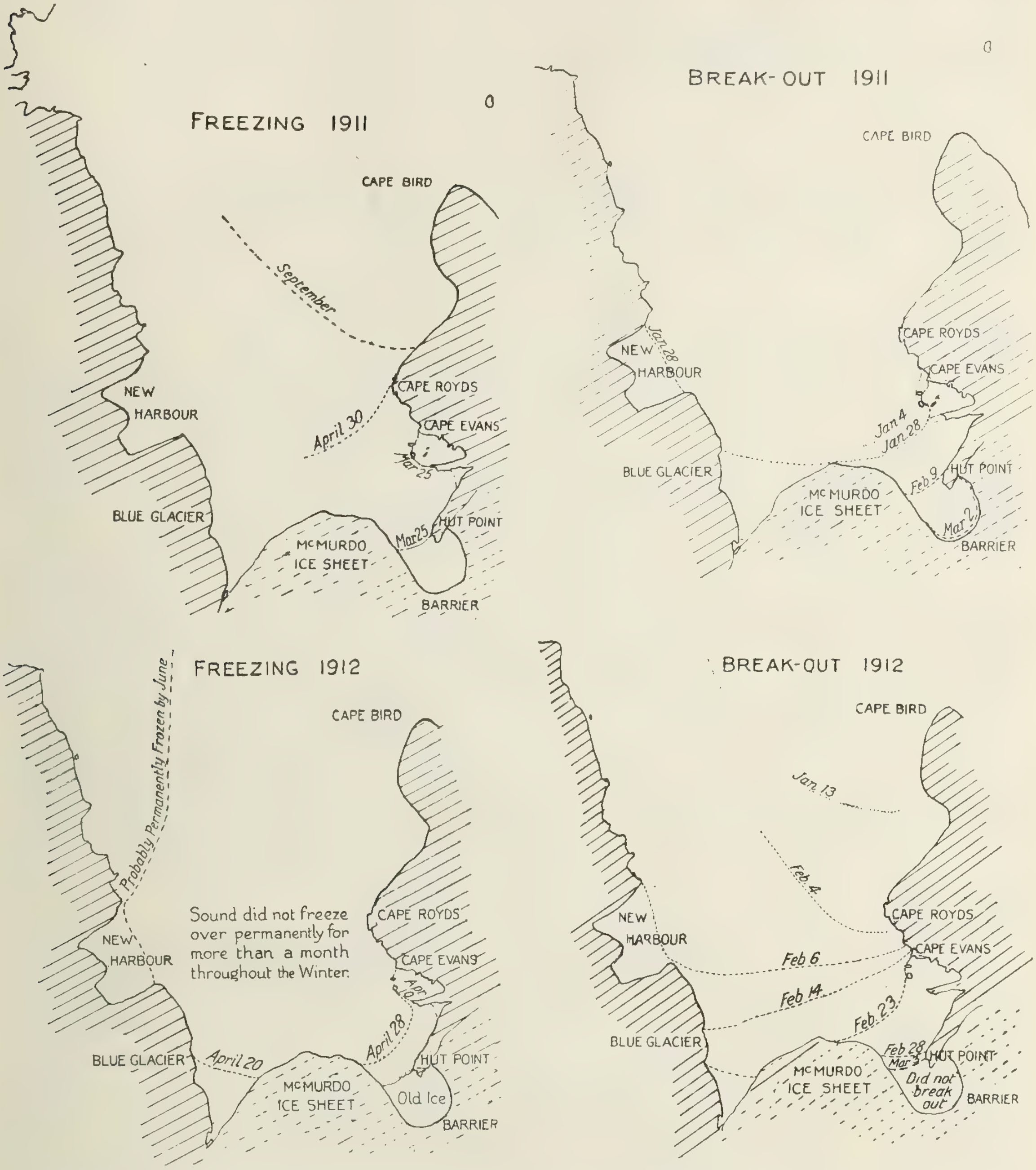

Fig. 19.—Diagrams to illustrate stages in the summer breaking out of sea ice and autumn freezing. Lines on the freezing diagrams represent lines of fast ice for the rest of that winter. On the break-out diagrams they represent lines behind which the ice was still fast on the given date.

The inference is that in the average season the ice at mid-November is still fast—though it may be thin and therefore dangerous to sledge travel—all along the Western side and as far up the Eastern side as the Dellbridge group of islands, and this inference is fairly well confirmed by experience.

The break-up of the fast ice, no matter how thick, is subject to great variations in date. Beyond stating the general principle that the earlier in the autumn the sound ice sets fast, the thicker it will be and the later the break-up, one cannot venture to set dates or limits to the time. It should be noted, however, that the sound ice is more likely to break up and float north after a southerly storm than during it, and it is just the sunny, calm days after it that are most risky for travelling on the sea ice. The last ice to go is that in New Harbour, the bay south of Blue Glacier, and the inlet south of Cape Armitage.

Of the route up the coast there is the evidence of three parties. In the autumn a journey on the sea ice off the coast would be very risky indeed, but in the spring on these three occasions the ice was fast though not always very thick, especially south of Butter Point.

Currents and Ice Movements.

The drift of the surface water in the Sound has been directly observed off the three headquarter stations on Ross Island, but elsewhere it is observed fairly well by tracing the movements of bergs and pack ice. The currents, as shown by the blue arrows, are therefore fairly well authenticated, but their rates and the minor deflections due to islands and other obstructions are liable to variation.

The westward drift along the north coast of Ross Island is well known, and was directly observed by the *Morning* which, in 1903, was caught in the pack off Mount Terror and in a week drifted through the passage between Beaufort and Ross Islands into more open water. That this drift swings to the South in the Sound is also a matter of common observation, but how far it penetrates in that direction is entirely a matter of temporary conditions. Dr. Murray, of the *Nimrod* Expedition, thought that it always turned westward at Cape Royds, but true Barrier bergs and pack ice were constantly carried far south of Cape Evans. In January, 1913, for instance, the *Terra Nova*, when tied up to fast ice but a mile or so off the permanent ice-sheet in the south of the Sound, was threatened by several large icebergs, which drifted against the ice and remained there for some time before going off north-west.

The current coming from under the Barrier to the south of Ross Island is also well known. It certainly varies in rate with tidal and other conditions but apparently not in direction. It occasionally passes the Hut Point peninsula at three knots, but as it spreads into the Sound it becomes a drift rather than a current and, with the help of the prevalent S.E. winds, is responsible for the general ice movements towards the mainland coast. Though not shown on the map, the current was occasionally observed to follow the coast-line of Erebus Bay and sweep through the strait between Inaccessible Island and Cape Evans at a rate of three knots.

One example of this north-westward drift of all loose ice in the Sound is worth quoting. In March, 1911, a piece of the Erebus Glacier Tongue, three miles in length and carrying depots, was broken off in a blizzard. It was found the next spring, grounded and surrounded by fast ice off Marble Point, North of New Harbour, more or less intact.

In February of the next year it floated off the shoal and drifted out of further ken to the northward.*

Soundings and Shelter.

The soundings are taken from the *Discovery* and *Terra Nova* surveys with a few from that of the *Nimrod.* From the purely navigational point of view they do not disclose much of interest, no shoals having yet been discovered in the Sound except close inshore, shown on larger scale maps.

The question of harbourage is of great importance in this much frequented corner of Ross Sea. Remembering that the direction of the prevalent strong winds is south-east, it is clear that the best protection is to be sought on the West coast of Ross Island. Three localities offer themselves, Cape Royds, Cape Evans and the northern side of the Glacier Tongue. In the two former the holding ground is rocky and bad, while at the third the water is over 100 fathoms. Indeed, a safe anchorage for bad weather is quite out of the question, since, in addition to foul ground, the strength of the winds is unusual and would render any anchorage unsafe.

The alternative of tying up by ice anchors to the inner portion of the glacier tongue is, however, worth fuller consideration than it has received. It has been used several times for shelter in blizzards and for temporary quarters. The disadvantages are the islands and shore in the lee, should the ice anchors draw, and the movement of the ship in the swell against the ice wall. In consequence, no shipmaster has yet been content to let his fires out while in this place, but it is quite possible that an experienced ice-master would be content to trust his ship to winter against the tongue, having provided by fenders and extra lines against mishap until the ice has frozen round the ship, which would normally take place about the beginning of April.

The possibility of shelter in New Harbour or Granite Harbour has not yet been explored. The water would be deep, except in the northern half of New Harbour, and tying to the ice of the tongues would be the normal method. Good shelter from the south-easterlies could be found in either harbour, but the swell would be troublesome, and occasional local but strong westerlies would be experienced.

As a temporary cruising ground for whaling, the Sound would offer many advantages, the chief being the fact that, once open, the Sound is very rarely densely packed with ice, and there are shelters on both sides.

From admittedly inexpert observation, it has seemed that the number of whales, chiefly rorqual and killer, within the Sound is at least equal to that in the open Ross Sea, especially during January and February.

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* The depot on the fragment had been used as a primary point on the plane table survey up the coast. By a quaint coincidence it was being used as a point from which to resect at the moment it began to float away, and the resulting orientation of the table caused much consternation until the slow turning of the mass showed that it was moving.

MAP V.

WEST COAST OF ROSS ISLAND.

Scale 1 : 100,000. Projection : Rectangular.

The extent of this map has been chosen to include the three headquarters of expeditions, and consequently it contains the most detailed surveys which have been carried out in the region.

The same conventions as to the significance of firm and broken lines as in Map IV are kept, but snow-covered and bare rock areas are not distinguished.

Sources and Framework.

The basis of this map is the small unfinished triangulation carried out by Lieutenant Evans in the spring of 1911, which is discussed elsewhere. A small extension of it made by Lieutenant Campbell and C. S. Wright in 1912 gives a group of coastal points from Cape Royds to Castle Rock. The coast-line of Erebus Bay was traversed by Evans, and that of the S.E. side of the Hut Point peninsula is from an old compass traverse made by Dr. E. A. Wilson in 1903. The remainder of the detail on the map is from plane table sheets by the writer, controlled by a graphic triangulation and made at various times and on different scales.

The heights of the chief features are by theodolite angles and those on the route to the top of Erebus are from hypsometer and aneroid. The contour lines are interpolated between a number of Abney level altitudes and, except where in a firm line can only be regarded as approximate ; on the south side of Erebus they are very much generalised.

The only detailed surveying done before on the area of this sheet was in the environs of Hut Point and Cape Royds, and no detailed map was published prior to 1910. An excellent plane table map of part of the Cape Royds district was made by David and Priestley in 1908, but as this was not published until much later, a special set of sheets was made on Cape Royds (Map IX) and are used for this map.

Apart from the coastline, the framework is that furnished by the triangulation of the plane table itself. Since the sheets were, for that area, on the scale of 1 : 80,000, this should be sufficient to ensure no plottable error appearing. This cannot be claimed, however, on account of the rough home-made plane table outfit which was used, and because of the real difficulties of carrying the triangulation round the shoulders of Erebus.

The inset map of the summit of Erebus is merely a sketch map derived, as to the neighbourhood of Fang Glacier, from the plane table, and as to the summit itself, from the reports and measurements of the ascent party. It is inserted here in spite of its inaccuracy, since the topographical changes which are likely to occur during the next score of years may very well be much greater than the errors of the map, and, even as it is, it will be of some guidance to vulcanologists.

Routes.

The only routes over this area which call for remark are those marked on the map. The autumn route from Hut Point to Cape Evans was frequently used and was usually safe by the second week in April, or even before, and in any case provided a safe passage at least a fortnight earlier than one outside the glacier tongue. It involved the descent or ascent of a cliff about 30 feet high at Hutton Cliffs, where a permanent stake was left. As will be understood from the fate of Macintosh and Hayward in 1915, who were lost in trying the direct route in the month of May, this outside route cannot be considered absolutely safe until the ice on it is at least 18 inches thick.

An overland route all the way is quite out of the question except for a mountaineering party, the ice-falls of the Turk's Head Ridge being very formidable indeed.

The route to the summit of Erebus was very simple, and the sledge, left at 9,000 feet, might easily have been taken at least 1,000 feet higher by following up the Fang Glacier to its col.

The route from Cape Evans to Cape Royds over the Barne Glacier is not plotted, and a winding course has to be taken to avoid crevassed areas, reaching the northern side of the glacier at about 700 feet above sea-level.

Soundings and Harbourage.

The larger scale has allowed some inshore soundings to be plotted on this sheet which do not appear on Map IV, and others appear on the maps of the individual districts on this coast. The majority of these soundings were taken during the winter through holes or cracks in the ice.

The question of shelter for ships has already been referred to (Map IV).

Special Features.

The mapping of the Barrier Edge and its junction with Ross Island ice deserves some consideration, since only at this corner has there so far been any opportunity of studying it by continuous observation.

It is to be regretted that this expedition has no better map to offer of its features than this, but certain suggestions for future work may be of use.*

The line of the edge of the Barrier south of Cape Armitage will, of course, vary from year to year according to the extent of it broken off each autumn and is not worth an accurate traverse. On the other hand, some measurements as to its rate and direction of movement might be made half a mile or so within the edge by resection with a theodolite from a wide choice of near or distant peaks. Two or three different points would have to be occupied, as the directions of motion here must be to some extent converging. At the same time, some very remarkable " rolls " or pressure waves in the surface of the Barrier in the direction of White Island, caused presumably by this confluent motion, could be measured, the simplest method probably being to use the theodolite as a level and level back from the water or sea-ice level.

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* An attempt to survey the cliff edge of the Barrier by depression angles from the summit of Observation Hill was made by Evans. The results threw some light on the vagaries of refraction, but none at all on the actual position of the Barrier edge.

Along its junction with Ross Island there is much for the student of glacier motion to note as to the behaviour of the Barrier, and hand instruments only would be required for his measurements. A careful compass or plane table traverse would be necessary, and the addition of a hand level would enable sections of the waves and pressure chasms to be made very quickly. Some stakes placed across the curious "Ice-moraines" and measured at a later date would probably reveal some peculiarities of motion due to the peculiar circumstances.

MAP VI.

GRANITE HARBOUR.

Scale 1 : 100,000. Projection : Rectangular.

This map is intended for the study of land forms and also to record on a fairly large scale the positions of ice fronts in the summer 1911–12, with a view to comparison at future times.

Source and Framework.

The area of the map was surveyed by the writer with a plane table on the same scale as it is printed, taking up four sheets. Larger scale maps were made of certain localities at the same time, and these were used by reduction.

In the original plan the survey was to be controlled by a framework of points fixed by theodolite observations. For various reasons these observations were unsatisfactory and could not be used for the purpose, and the only control is that furnished by the graphic triangulation.

Careful observations for latitude and time were taken by Lieutenant Pennell from the ship when lying close to Cape Roberts, and the point is therefore used as origin for the geographical co-ordinates.

For the relative positions of the chief features the map is therefore not to be trusted, but for the accuracy of local detail it should be satisfactory, especially for the positions of the fronts of ice-cliffs and tongues, over which special care was taken.

Granite Harbour was entered by the *Discovery* in 1902, but no survey was made, and, except for the observations from outside the harbour by Mawson in 1908, no data were available.*

The convention of firm and broken lines for surveyed and sketched detail respectively is followed here as in the former maps. The altitudes were taken with the theodolite for the main peaks, the distance being taken from the plane table sheets. They should, therefore, be accurate to within 100 feet for those near the harbour itself, but the height of Mount Gran, for instance, may well be some hundreds of feet in error. The contour-lines, where firm, are controlled by a large number of Abney level altitudes.

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* As an instance of the illusions common in such an atmosphere it may be mentioned that although the *Discovery* steamed almost as far up the harbour as Cape Geology, the existence of the huge glacier tongue only 2 miles away was never suspected. Nor was it distinguished by the 1912 party until the hill behind the cape was climbed.

The map may be taken as a fair specimen of what can be done with a plane table in a summer sledge journey without special devotion of time to it. Had the theodolite control proved effective, the map might have served all ordinary purposes for a long time to come, but, as it is, many major errors of position will probably be found by the next comers.

Routes.

The only route of special interest is that marked on the map, which was followed by the party in returning southwards over the Piedmont Glacier, the sea ice having broken out from a short distance south of Cape Roberts. Many badly crevassed areas were crossed, and the party's freedom from mishap was due chiefly to the bright, sunny weather which held during the crossing rather than to any amenities in the route itself. In fact, it is not to be recommended, except that from all appearances any other route would be as bad, since it would have a direction parallel to hidden crevasses instead of across them. It was also quite clear that the going was better at least two miles from the coast than was the case close to it.

On the Mackay Glacier the party reached no farther than Mount Suess, and the first part of the ascent was made by portage over the Flatiron promontory. It could be made over the New Glacier also, and the travelling along the middle line of the main glacier was safe and easy. From the summit of Mount Suess, it appeared that a way on to the plateau could be found by keeping to the southern side of the valley and following a somewhat devious route.

Special Features.

One of the features of the sea ice in the harbour, which considerably limited the party's movements until its cause was discovered, was that on the seaward side of all the capes, such as Discovery Bluff, the land was separated from the sea ice by a channel of water with ice on it progressively thinner as one neared the land. After several duckings and some awkward situations for the sledge, it was discovered that the channel was due to the motion of the central glacier tongue, which also causes the permanent shear cracks shown on the map. The effect of this motion, after causing the crack, is to pile up the sea ice into pressure waves on the inner side of promontories and push it away from the land on the seaward side, an action which goes on throughout the winter and spring. The solution of the difficulty is to cross the shear crack well out from the point—and in midsummer the cracks may be 30 feet across and have to be ferried over—and approach the capes from the landward side.

Soundings.

No soundings were taken, but from the fact that there were very few grounded bergs in the harbour, we may infer that the water is deep almost to the end. The

Discovery went up as far as Discovery Bluff, but there is no doubt a ship could get up to the Devil's Punchbowl.

In connection with the harbour's facilities for shelter, it should be noted that on Cape Geology there were many stranded blocks of ice, which had been thrown by a swell some 6 or 8 feet above tide level, showing that heavy waves can penetrate well up the harbour. The Punchbowl would probably be the most sheltered spot and was indeed mentioned as such by Captain Scott in 1902.

In spite of the permanently cracked state of the harbour ice, it does not break out early in the season. The *Discovery* found it just breaking out on January 20 when she was there, but in 1912 it did not go until some date later than February 5.

Captain Scott was much impressed with the security of the harbour, especially on account of the smooth surface of the sea ice within it found both then and in 1911–12. This smooth ice is due to shelter from winds, which breaks and piles up the early autumn ice into hummocks on all lee shores. In short, for vessels cruising in the sound during February, the inner harbour offers shelter and security from pressure if frozen in.

MAP VII.

THE FERRAR-KOETTLITZ REGION.

Scale 1 : 200,000. Projection : Simple Conical.

From the point of view of the geologist and the ice specialist, this is perhaps the most important map of the series, and although a good part of it is in broken line, that is to say, based upon sketch surveys, it is hoped that it will be of value for their purposes.

Sources and Framework.

The basis of the map is that produced by Lieutenant Mulock from the surveys of Armitage and Ferrar and from some observations of his own on the *Discovery* Expedition. Minor corrections and additions have been made to that map where later data were available, while the part north of the Kukri Hills and on the upper Koettlitz Valley is new. The original map was a compilation, and the present one is a compilation also of a series of more or less independent local surveys made from rounds of angles with the theodolite by C. S. Wright.

To plot these angles a selection of points had to be assumed correct, and choice was made of Mount Lister, the Pimple and Mount Huggins for the coastal strip, and Obelisk and Knobhead Mountains for the Ferrar and Taylor Glaciers.

It was obvious when fitting the observations that there were bad discrepancies in the positions of these points taken from the original map, and a certain amount of arbitrary adjustment was necessary. Such adjustment seriously discredits the map as a whole, but does not greatly affect its value for the purposes stated above.

The map, as published, is the result of a six weeks' journey up the Ferrar and the Koettlitz Glaciers in the autumn of 1911, when other subjects for observation than survey measurements were the chief duty of the party. In consequence, the sources for plotting the detail are extremely varied. Photographs, sketches, small contoured plans sketched by eye by the writer, and other somewhat untrustworthy records have all been used, involving considerable labour without a corresponding satisfaction at the result. It is thought, nevertheless, that for individual valleys and local detail the errors will not be found to be unreasonably great, and the map perhaps fulfils the first requirement, to constitute an improvement on the former one. The plane table was not constructed then, and only the coastline by Cape Bernacchi comes from the sheets surveyed in the following year.

It will be seen from the general relief that the district presents no difficulty from a surveying point of view and could be mapped to a similar scale without plottable error by a skilful plane-tabler in a few weeks, even without the assistance of theodolite control.

It should be noticed that the Upper Ferrar Glacier, which was not visited by the 1911 party, has been amended. This is because the original sextant survey figures of Ferrar were found and replotted in the light of more accurate local knowledge than Mulock had.

A word with regard to the naming of the features on this map and that of Granite Harbour is necessary. The party responsible for the survey adopted the useful custom of giving names rather than numbers and letters to all distinctive features met with. This simplified references in the notebooks and in conversation, the principle in this case being to endeavour to name a feature from its appearance and, failing that, to fall back upon a geologist—two of the party belonging to that fraternity. These field names were, of course, to have been replaced in the final maps by others chosen by the authorities of the expedition. Owing to the death of Captain Scott and also to the need of haste in bringing out the preliminary maps for the narrative, this was never done. None of the *Discovery* names have been altered, but some have been somewhat delimited, for instance, the Ferrar Glacier, first surveyed and examined by Ferrar, has now a series of named glaciers leading to it or from it, including the Taylor Glacier, called after the leader of the 1911 party.

Routes and Special Features.

No routes have been inserted on the map, but one or two remarks on the subject are called for in connection with travelling on the Koettlitz Glacier. The detail of the rough ice on the lower glacier is the result of five days' very slow progress over some 20 miles, at the end of which it was found there was a smooth and easy route at the northern side over a wide thaw-stream. The easy route had indeed been found and used by a *Discovery* sledge party, but, the facts not having been published or mapped, it had to be re-discovered. Owing to this delay, an important duty on the programme of the party could only be partially fulfilled. It was intended to investigate thoroughly the peculiar longitudinal valley below the Royal Society Mountains, called in the *Discovery* maps, Snow Valley. Since it lies just where the entry of "Foothills not surveyed " occurs, no strong evidence on the subject is given by this map. From observation—in dull weather—from the top of Terminus Mount, however, it was seen that it did not exist as a single valley but rather as an indefinite group of low foothills with some hint of low valleys between running away from and not parallel to the escarpment.

There are certain points on the map which were plotted with special care with a view to comparative measurements to be made in the future. The first of these is the snout of the Taylor Glacier, a glacier which may perhaps be regarded as a suitable indicator of the supply of ice from the plateau, since it is fed from there and not from neighbouring slopes, and, unlike most Antarctic outlet glaciers, fails to reach the sea. The snouts of the Canada and Commonwealth Glaciers in the same valley were fixed as to extent by plane table and may be regarded as fairly correct. Those of the glaciers south of the Ferrar Valley are less accurate, the Hobbs and Davis being the best. The junction of land and sea ice off Cape Chocolate is another important line ; it was not surveyed but cannot be more than half a mile in error.

It should be noted that this map replaces one of the same area published with the narrative of ' Scott's Last Expedition,' which was compiled at short notice and included many errors since detected.

MAP VIII.

CAPE EVANS.

This map was drawn by Lieutenant Rennick in 1914 from data furnished by Lieutenant Evans and, except for a few minor additions, has been left as drawn.

It is based upon the triangulation of the neighbourhood already referred to, and the coast-line and detail was obtained by traverse with sextant and sledgemeter. A plane table map of the Cape itself was also made, but, as it contained too much detail for the reduced scale of this map, it has not been used.

The Barne Glacier face from High Cliff northwards was traversed by Wright with a tacheometer and is probably more accurate than the rest, a point worthy of note in view of future measurements to obtain figures for the advance or recession of this glacier.

There are some features of interest to navigation, which may be mentioned. The most important is the shoal off the end of the Cape, whose position is given approximately by the dotted lines. The name is perhaps not quite accurate, since the shoal is of hard rock, a continuation of the Cape, in fact. When the *Terra Nova* discovered the shoal by going aground on it, she had 17 feet of water at the bow and 39 feet at the stern.

It is clear from the soundings farther out that there is a submarine ridge to Inaccessible Island of a mean depth of 60 fathoms. Numerous bergs coming from the North become stranded on this ridge, and some of those of 1911–12 are plotted with their approximate heights. The presence of the shoal has another effect which is worth giving here as a warning. The increased current over the ridge melts the ice from below in the summer months and produces thin patches or open water-holes in it long before it has broken out. It was in one of these thin patches that one of the motor sledges sank and was lost while landing it from the ship.

In the autumns of 1911 and 1912 the sea ice when first formed was repeatedly blown out to the north, but at a certain stage in its growth, when about one foot thick, it resisted ordinary gales to the south and east of a line from the Cape to Inaccessible Island. This line was the limit of the fast ice for but a few days in 1911, but in 1912 the North Bay ice repeatedly blew out during the winter back to the same line.* The same line is of importance during the break up of the ice in the summer, there being usually a pause at this line before the inner ice goes out.

MAP IX.

CAPE ROYDS DISTRICT.

The Cape Royds district was surveyed by plane table on a few fine days of December, 1912, on a field-sheet scale of 1 : 10,000 as a part of a geological survey. Since it includes the headquarters of the *Nimrod* Expedition and a hut which will be serviceable for many years to come, it is published, without the geological data, as an addition to the plane table survey by David and Priestley, which did not cover the whole area.

Its interest is not confined to its historical associations, for the glaciers at either end of the area are moving and will recede or advance as time passes, and the lakes will alter their shape.

The contours were interpolated on the ground upon a series of Abney level and aneroid heights and should be accurate to within 10 feet on the lower levels. Especial care was taken with the coastline, although, owing to the presence of a heavy ice foot round it at the time, the real shore line was not always visible.

In this survey a difficulty was met with which will often occur in comparatively level areas in polar regions. The amount of snow on the ground at one time varies so greatly with the time of year that not only are the distinctive marks of one period lost at another but any attempt to map the bare land as opposed to permanent snow is defeated.

The map calls for no special comment, except that it shows two temporary shelters for a ship in Backdoor and Horseshoe Bay, both of which have been used as such.

MAP X.

HUT POINT PENINSULA.

As in the case of Map IX, this map is published partly because it was the head-quarter district of the *Discovery* Expedition. It was surveyed by plane table in the early spring of 1912 on its own triangulation. It may be taken as an instance of what may be done with a plane table even in severe weather, the temperature averaging —10° F., during that time with some winds strong enough to blow the table over.

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* The same may be said of the winter of 1915 when the *Aurora*, moored in North Bay opposite the Hut, drifted off with the ice during a gale in May.

The coastline had to be traversed with the table after the summit of the ridge had been completed but presented no special difficulties. Heights were taken by aneroid and Abney Level as a basis for the contour lines. The unusual interval of 75 feet is used, as the heights were not numerous enough for a 50-foot interval, and many underfeatures would have been lost with 100-foot interval. They were, of course, interpolated on the ground.

A special feature of the map is the large number of soundings upon which approximate submarine contours have been drawn. Nearly all these soundings were taken by Lieutenant Barne in the winters of 1902 and 1903 during the *Discovery* Expedition. No use had been made of them, and permission to incorporate them in these maps was kindly given by Lieutenant Barne, who took most of the soundings unaided, through holes in the ice. They exhibit very clearly the steep submarine slopes as a continuation of those above sea-level.

MAP XI.

MAP OF EREBUS BAY—ROSS ISLAND.

Scale 1 : 50,000. Projection : Rectangular.

The purpose of this map is to place on record the general topography of this area as it was in 1911, as a basis for comparison with future maps when ice movements, etc., have made changes.

Sources and Framework.

No detailed map of this area has been available before. The surveys by Mulock in 1903 did not include any such detailed work, though they did fix approximately the leading points in this bay.

The framework of the map is the triangulation by Lieutenant Evans made in the spring of 1911, which has been discussed above, the accuracy of which is amply sufficient for the purposes of this map. Three of the main stations of the triangulation come on to the sheet, namely, Tent Island, Turk's Head and Turtle Rock.

The coast-line, including the outline of Glacier Tongue, was walked in with the sextant by the method described in Wharton's Hydrographical Surveying, large bays being followed in to the end and small bays being plotted by offsets, paced or estimated from the main line. The heights of the cliff were estimated where below 30 feet, and measured by sextant where above that figure. Particular care was taken with the sinuous outline of the tongue. The contour lines and detail beyond the coast-line are taken from plane table sheets and sketches by the writer. In the localities of Tent Island, Turk's Head and Castle Rock the contours may be taken as fairly satisfactory, as they are interpolated on the ground from spot heights given by the aneroid or the

Abney level. But on the featureless snow slopes at the back of the bay the contour lines are not surveyed and can only be considered as a general guide to the form of the surface.

Features and figures in black refer to bare land, those in blue refer to ice or snow and the usual signs for large snow drifts, moraines and crevassed areas are adopted.

Soundings and Currents.

The soundings on the map are from various sources, chiefly from the work of the *Terra Nova* in 1911, and show the rapid deepening which is common all round Ross Island. They are printed in sloping type to distinguish them from the heights of islands, etc., which are in upright type. Further soundings are required by the tongue and amongst the Dellbridge Islands to establish their relationships with each other and the main island.

No direct observations of the currents are available for this area, but since the 3-knot current observed at Cape Evans was from the direction of Turk's Head it obviously affects Erebus Bay. In fact it seems probable that a section of the current passing round Hut Point to the northward traverses the bay from south to north, escaping over the shallow sill between Inaccessible Island and Cape Evans. Bergs which had obviously calved from the ice masses in the vicinity of Turk's Head were often grounded near Cape Evans, and in any case the direction of the prevalent wind, south-east, would cause a general movement of the loose ice in the bay in the same direction.

The sequence of the freezing and breaking up of the sea ice in this area is dealt with in the description of Map IV, McMurdo Sound.

Anchorage and Shelter.

As far as known no attempt has been made to find an anchorage in the bay, and the only possible places would appear to be to the north-west of Turtle Rock or Big Razorback, but in either case the ground is likely to be rocky and not very suitable. Shelter from the strong south-east winds would be more complete behind the tongue itself and this has been much used. There are no anchorage soundings until one approaches the base of the tongue, but there are many places along the North side of the tongue which afford good holding by ice anchors. With ice anchors well sunk in the crevasses and provision made to avoid excessive bumping by the slight swell a snug berth even for a winter quarters might be found for a ship. The nearer the root of the tongue she was moored the sooner would she be frozen in, and there seems to be no record of the ice inside the Dellbridge Group ever having been blown out during the winter. There is evidently a shallow bank between the Razorbacks and Turk's Head, but from the height of the stranded bergs this is not likely to be less than 30 or 40 fathoms in depth.

Special Features.

The chief object of this map is to call attention to features which are susceptible to change and will require re-measurement at some future date. First among these is the Glacier Tongue. A detailed description of this and other tongues is to be found in the Glaciology memoir* of this expedition, but much remains to be done in connection with its study. The map records as near as can be done two former positions of the end of the tongue showing a recession by breaking off of some 4 miles since 1902. Such a figure is of no real interest over such a short period, especially as the bulk of the recession took place *en bloc* during a gale in March, 1911. The tongue is obviously moving and possibly with some rapidity, but no figure for its rate of movement has yet been obtained. Since a measurement over a long period of time, that is to say several years, is much to be preferred to one over a short period the detail of the tongue has been plotted with some care in the hope that some of the details will still be recognisable for a future expedition when a re-measurement should give a reliable figure for its mean movement.

It may not be out of place to remark that the simplest method of making a determination of the motion over a short period would be to set up a stake or mark on the tongue in transit with an observation point on one of the Razorbacks or on Turk's Head and with some marked feature, of which there are many, on the Hut Point Peninsula. The line should, of course, be as nearly at right angles to the tongue as possible. After a suitable lapse of time, such as a winter, the movement of the stake would be measured directly by a chain by re-establishing the transit line and measuring from it.

The ridges or rolls on the tongue itself, which are marked in the map, were not surveyed but were inserted on it diagrammatically from a sketch, the number of the rolls being correct, but their distribution being unreliable. It seems probable that the cause of these persistent features will only be established by careful surveying at the root of the tongue.

Other work connected with the tongue which is desirable is to establish the point of flotation, either by soundings, which could be done through the numerous cracks in the sea ice, or else by observations of the tide crack. It is obvious from the large number of stranded bergs near the base of the tongue that there is a good deal of shallow water there and possibly obstructions which may be connected with the rolls.

The incipient tongues close to Tryggve Point and farther to the north are also probably in rapid movement, but their measurement presents rather more difficulty. The general appearance of the landward half of the tongue is shown in Fig. 20, which is from a sketch made from the Eastern summit of Turk's Head.

MAP XII.

THE INNER HARBOUR, GRANITE HARBOUR.

CUFF CAPE, GRANITE HARBOUR.

THE DEVIL'S PUNCHBOWL, GRANITE HARBOUR.

These detailed locality maps were all surveyed by plane table, and the surveys were originally made in connection with the geology of the district. They are published

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* 'Glaciology,' pp. 193–205.

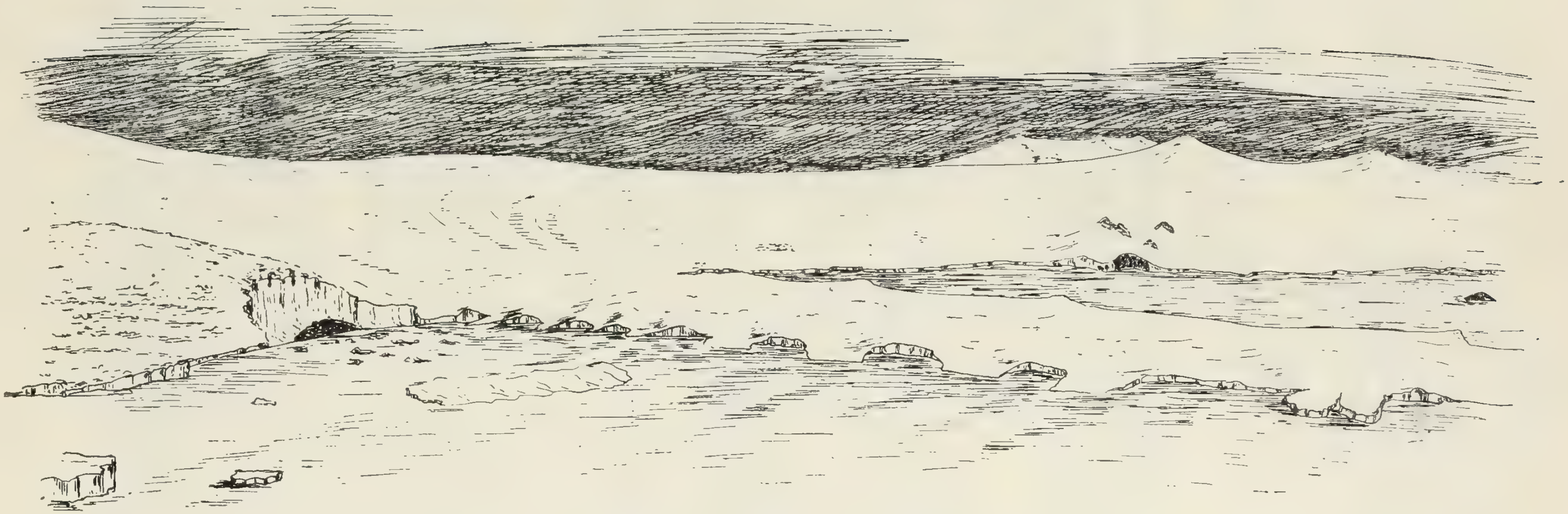

Fig. 20.—Sketch of the Glacier Tongue from the summit of Turk's Head.

in this series since they form a basis of measurement of the changes which may take place in time, especially of the main glacier tongue.

The recently exposed Cuff Cape and the extraordinary saddle ridge leading to the Devil's Thumb are also features which will alter rapidly under the local conditions.

The localities are dealt with from a scientific point of view in the Reports on the Physiography (by Taylor), Glaciology (by Wright and Priestley) and Geology (by Debenham) of the expedition, so that no further remark seems to be called for in this description.

MAP XIII.

ROBERTSON BAY AND CAPE ADARE.

This map was plotted in 1914 by Lieutenant (now Captain) V. L. A. Campbell from his own surveys made in 1911, when the party under his command wintered on Ridley Beach.

Sources and Framework.

Although many ships have visited Robertson Bay, the only map published was one drawn by Colbeck, the surveyor of the *Southern Cross* Expedition under Borchgrevink in 1899. The map was published with the narrative without explanation of how the work was done, and, though its main outlines are correct, it obviously makes no pretence to accuracy in detail.

The observations for the position of the hut on Ridley Beach appear to have been carefully carried out, and Colbeck's determination is adopted by Campbell for his map.

A series of journeys were made by Campbell's party to the south end of the bay and along the coast as far as Turret Island, and the leader carried out his survey on these journeys.

The basis of the map is a series of theodolite observations from each end of a long base (17 miles) laid out on the sea ice by sledgemeter. By these the salient features of the coast were fixed, and the detail was surveyed by traversing. On account of the thin ice away from the land the routes followed had to be close inshore, and the steep-to coast prevented any view of the magnificent peaks some miles inland, which are, therefore, not included in the map.

A series of aneroid heights along the summit of the Cape Adare Peninsula were taken by Priestley, and these are entered on the map. Elsewhere no altitudes were taken.

In order to give some idea of the relief, the writer has inserted form-lines at an approximate interval of 500 feet. This was done by measurements from the excellent panoramic photographs taken by Levick, the surgeon of the party, but no great reliance can be placed on them.

Routes.

No routes are marked on the map, since they are all over the sea ice and involve no special obstacles. The insecurity of the Bay ice precluded any short cuts across the Bay, and the direct route even from Ridley Beach to Point Penelope was attended with some risk, which was increased by the fact that in very few places along the coast was it possible to get ashore from the ice, while travelling overland was possible only to a mountaineering party. Ridley Beach is, in fact, virtually cut off from the mainland except in late winter and during the early spring months. Even then, the possible journeys are limited, since it was found that north of an approximate line from Cape Adare to Turret Island the ice was constantly blown out during the spring.

Special Features.

The most interesting feature of the locality is the beach itself, a small map of which appears as an inset. This was surveyed by a miniature triangulation and can be considered accurate. It is probably the most important part of the map, since the beach is changing considerably in form and area, and some measure of its change may, some day, be gathered by comparison with the map.

Another feature liable to rapid change is the glacier tongue of the Murray-Dugdale Glaciers. On the *Southern Cross* map this appears to extend some five miles North of Duke of York Island, so that it had broken back considerably in the interval of 13 years between the surveys.

Currents and Ice Movements.

The eastern side of the Bay, but not the western, is subject to extraordinary local blizzards, always from the South-east, and these usually blow the ice out as soon as it has formed, in a north-westerly direction. In addition to the wind as agent of removal, there is a very well-defined current which sets in and out of the Bay, apparently as an offshoot or eddy of the main drift, as it comes round Cape Adare, but affected also by the tides. Pack ice and bergs were often observed to set into the Bay with the tide passing the beach at a rate of over 5 knots and later to pass out again at a similar rate.

This strong current is obviously due to comparatively shallow water off Cape Adare, indeed, it seems probable that the existence of the beach itself is largely due to the deposit of pebbles by these same currents, much in the same way as the boulder beach of Westward Ho ! in Devon has been formed.

Harbourage.

The Bay is comparatively shallow, for although the soundings are very few in number, grounded bergs are common almost anywhere on the eastern side. From the point of view of holding ground, there is good anchorage therefore. Nevertheless, the Bay has a bad reputation on account of the currents which at very short notice bring in heavy pack. The usual anchorage is South of the beach where the soundings are, but even here the pack will swing round and beset the ship in a short space of time.

The strong and sudden winds from the South-east are also a menace to ships, and, although some shelter from these may be had by going to Protection Cove at the head of the Bay, their force on occasion would be dangerous to any anchorage.

It seems from past experience that as a rendezvous Robertson Bay is rather to be avoided, and fires would have to be kept banked unless there was a certainty of no pack ice in the offing.

In entering the Bay a course well clear of the Cape should be kept, on account of the strong tidal currents and some shoal water there, which is not mapped. The *Discovery*, when entering in 1903, had a sounding of 5 fathoms surrounded by deep water, and Ross actually reported rocks awash somewhere close to the Cape.

The actual experience of the Bay by the *Terra Nova*, as described in a note by her captain, the late Commander H. L. L. Pennell, is appended :—

Approaching Camp Ridley from the North—

Soundings shoal gradually from seaward from 80 fathoms in, but there appears to be a ridge running approximately N.80.W. from the extreme point of the Cape.

Roughly on this bearing a comparatively shoal sounding was found each time (on January 3 and 4, 1912), the least water obtained being 10 fathoms some 3 to 4 miles off the Cape.

Farther out on this bearing 20 fathoms was found with 30 fathoms inside it in the Bay.

On January 3 and 4, 1912, anchorage was found in 7 fathoms on the North side of Ridley Beach in water with comparatively little tide. Here the Bay was clear of ice for two or three hours, when the remainder of the Bay was nearly full, and there was heavy pressure in the pack on the south side of the beach.

This anchorage, however, was only tenable for two or three hours on both days owing to the pack finally setting in.

On February 18-19, 1911, the ship anchored on the south side of the beach in 13 fathoms and maintained this position for about 36 hours. This is only possible when the Bay is nearly clear of ice, as the tidal streams sweep the pack, when there is any in the Bay, past this side of the beach.

While anchored for two days (February 18-19) on the south side of the beach (as above), it was found that the tidal stream set for over 20 hours out of the Bay in this spot. The remaining few hours being practically slack water here.

The pack, setting in with the flood stream in the middle of the Bay, when rather over half-way down the Bay, curved round to the eastern side and set down towards Camp Ridley, the main stream still flooding.

When the main stream turned, this pack inshore came at an accelerated rate.

When the main stream first began to flood, there was slack water at this anchorage.

Unfortunately, proper observations could not be taken owing to press of work.

The pack in Robertson Bay was found to be very heavy both seasons.

Robertson Bay should be navigated with care. The pack is heavy, the icebergs often aground and the tidal streams very strong, while the wind in gales is often of extreme violence. Besides these, the ridge guarding the entrance may possibly rise high enough to form a dangerous rock.

MAP XIV.

TERRA NOVA BAY.

This map was plotted by Lieutenant Campbell from his own surveys made in the late summer of 1912, while sledging up the Campbell and Priestley Glaciers.

The control is by latitude and azimuth sights fitted on to the position of the landing place in Evans Coves, which was determined by sextant observations from the ship. The map, therefore, is not to be regarded as very satisfactory, and both the coast-line and the Mount Nansen Foothills had to be sketched in from a distance.

The heights were obtained by theodolite angles, but those at a distance from the party's route, such as Mounts Baxter and Levick, are probably very untrustworthy. The contours were interpolated by the writer from photographs and can only be relied upon as a general guide to the land forms.

Special Features.

The most interesting feature on the sheet is Mount Melbourne, a recently extinct volcano whose characteristic graceful cone is a landmark for many miles up and down the coast. The party did not get close enough to survey its slopes, and the contours in broken line are only from distant photographs.

The level plain of ice formed by the confluence of the main glaciers is important as it forms the first stage of any sledge journeying in this area. For the most part, it is uncrevassed except close to land and may be considered the counterpart of the McMurdo ice-sheet further south.

Particularly worthy of note is the fact that the moraines, as shown in the map, disappear below the surface soon after the comparatively stagnant ice-sheet is reached but re-appear at the coast.

The snow-drift, in which Campbell's party had to endure a winter's hardship, is on the seaward side of Inexpressible Island facing the shallow bay. To ameliorate the hardship of the next party to be similarly situated, a food depot was established at the northern end of the island in 1913, sufficient to last them for the journey down the coast to McMurdo Sound.

The coves are formed by the recession of the ice round this island and are apparently free from dangers to navigation. As stated in the description of Map I, the water of Terra Nova Bay is often free from pack ice when it is densely packed 20 miles off shore, owing to the diversion of the stream by the Drygalski Glacier Tongue. Consequently, the best direction of approach is from the north-east.

The Drygalski Tongue is also responsible probably for the late date at which the sea freezes in the coves, the bottom water coming from under the tongue being slightly warmer than the surface water.

CHAPTER VII.

SURVEY WORK OF THE FUTURE.

One cannot spend the spare time of some three years in examining the irregularities and difficulties of polar maps and surveys without coming to some conclusions as to more satisfactory methods and equipment for future work in similar parts of the world. Further, one is emboldened to set down some of these conclusions, since there is an almost total absence of guidance on these matters in former narratives for the polar traveller who finds himself called upon to carry out surveys under the very special conditions which prevail. On some of these points there is complete agreement with other members of the expedition, but on others there is no unanimity, and the writer is advancing his own untried suggestions.

Something has already been said as to the performance of the instruments used, and certain suggestions for their improvement have been offered. Something also has been said as to the absolute necessity for organisation of the work even to small details. It is proposed now to discuss the applicability of survey methods as yet untried, or at least unproved, in the Antarctic regions, though they are fairly familiar to workers in the more accessible and one may say the more populated regions within the Arctic Circle.

There are certain fundamental characteristics of practically all expeditions which must be carefully borne in mind, for it is upon their account that these suggestions are modified in various directions. To begin with, a polar expedition is very rarely equipped with practised topographic surveyors, though this remark should be limited to British expeditions rather than to foreign. On the other hand, there is often a fair number of expert navigators who can carry out marine surveys, and, under direction, can cope with most of the special methods of topographical survey. It must be remembered, however, that almost all the members of an expedition are called upon at some time or other to take observations with survey instruments. It is not to be supposed that any change in the selection of scientific personnel for an expedition is being suggested, nor does the writer hold any brief for the topographic fraternity, indeed it is to be expected that in the future as in the past survey work will be a very small part of the work of any antarctic expedition. Not for a very long time to come will several nations vie with each other in producing almost annual surveys—with an almost annual crop of fresh place-names—of parts of the Antarctic Continent as has been done, for instance, in Spitsbergen. Expeditions, then, will continue to have little time and a small personnel to deal with the survey part of their programme and the organisation must be planned and the methods selected with that in view, and this must be done at an early stage and not left, as so many such things are left, for settlement on the voyage South. One has memories of seeing groups of harassed members of an expedition sitting at a wardroom table and grappling with the intricacies of polar sledge-navigation in the intervals of keeping watch, and it must be confessed that the teaching bore small fruit.

It must be repeated here that the object of polar surveys can very rarely be to attain an accuracy comparable with that expected in temperate and habitable countries. Polar maps, of all maps, deserve the gentlest criticism, and indeed usually obtain it, but even the most kindly critic is entitled to ask the question: " Can you give me the approximate error of those positions ? " It is not the error itself which comes up for judgment but ignorance of the error. Bearing in mind, therefore, that the object is to produce maps of a rough but known accuracy, usually of a route traverse type and from observations taken by men not specially trained, we may now proceed to discuss the methods best adapted to that object.

Apart from difficulties due to weather conditions the most important factor governing survey work is the shortness of the polar season. Adding to that factor the embarrassment of detail usually seen from any well placed survey station, it is clear that a method involving the least expense of time in the field and the most concise record of the observations from a station is the most desirable.

With such conditions the methods of photographic surveying and of plane tabling comply very well while the ordinary traverse methods are not at all adapted. It is true that both need a control for the best results over large areas, but that will be necessary in almost any case and would need little or no extension for those two methods.

Neither of these methods are new and both have been tried with great success in the Arctic regions, but since they are more or less new to the Antarctic and since also there seems to be a rooted idea that the conditions in the South are too severe for similar methods to be used it will be necessary to expand the theme somewhat. Captain Scott himself, who was an extraordinarily careful observer and surveyor when called upon, was quite convinced that the field pencil-work required in plane tabling would be impossible in the weather conditions to be met with and was not converted to its use until a plane table map of the vicinity of Cape Evans was produced for him in a few days of early spring weather.

In photographic surveying the principle is to occupy a series of stations fixed by some other means and take a round of photographs at each with a carefully levelled camera. These when developed can be measured and will give intersections for subsidiary points from which the detail is sketched in, also from the photographs. The system is a well tried and official one in such regions as Alaska, the Rocky Mountains of Canada and Spitsbergen for instance, and there is no need to commend it as a reliable method. One has the choice of a variety of cameras specially designed for the work, but most of these are quite out of the question on account of their weight or their complexity. What is suggested as the best type for the conditions of sledge-travelling is the panoramic film camera. The loss of accuracy by using films instead of glass plates hardly enters into the question while the saving of weight is of supreme importance. They can be manipulated in cold weather and, with special precautions, in fresh winds, and are no more intricate than any other fixed focus camera, a point of great value when many of the photographs will be taken by men who are not concerned with either photography or surveying in particular. A camera of this type was used by the writer in the early spring without any difficulty that could not be overcome by slight variations in design ; it was, in fact, far simpler to use than any camera with a shutter or other small movable parts. It was not used as a survey camera nor was it taken on sledge trips, but it could easily have been so used, and there is little doubt that it will give just as good results in the Antarctic regions as it has in Alaska.*

For more accurate work, where weight is not of such importance, another photographic method is recommended. The practice of stereophotographic survey has not yet reached an advanced stage in British surveys although it has been used for large scale work on the Continent for some years. It has many advantages over the single plate method and although the field practice is more complicated in that something more than a button has to be pressed, it is well within the powers of any one able to set out a short base and take photographs on parallel axes from either end of it. It is a method with a future before it and instruments are already in use which will plot the map from such photographs almost automatically.

The scheme of control for either system of photographic survey is a question which must be considered more or less on the ground, and it is sufficient to say that it would be just the same as for a properly controlled plane table survey.

In any case, whether photographic methods as such are to be used or not there should be a general rule that all photographs of scenery taken by members of an expedition should be taken with the camera level and a record kept of the direction, focal length of lens used, etc., so that if necessary they may be used for measurement.

Rather more may be said about plane table methods, since they were given a fairly comprehensive trial on this expedition, and some useful experience was gained which should be of value.

In the type of route-surveys, which form the bulk of polar cartographic work, experience has shown that it is hardly possible with theodolite, sextant or even compass to bring back sufficient data to construct a really detailed map of the route. Under even the most favourable circumstances, it means copious notes and measurements and sketches, which have to be reduced and plotted when far away from the area they represent.

It may perhaps be questioned as to whether there is any real value in detailed maps of such unfrequented parts, but it is a fact that it is more often the detail than the framework of the map that is of vital importance to the man who is using the map as a guide in the field, the use to which most surveyors would hope their maps to be put.

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* *See* ' Use of the Panoramic Camera in Surveying,' by J. W. Bagley, United States Geological Survey Publication, for an excellent description of the instrument and its application.

The kind of information which a sledge party requires from its map is where sea ice and land ice meet, where the coastal ice is accessible, where crevassed areas exist and so on, and such things on their map are far more important to them than the knowledge that the few peaks in sight are correct to within so many yards. Again, to the scientific user the actual detail of snow surface, shapes of glaciers, outcrops of rock, etc., placed on the map are just as essential for his deductions as are the general outlines. It is because this is not fully recognised, that we find such an appalling amount of time is wasted in re-discovering features. A party will visit an area for the first time and find by trial and error, let us say, that a certain glacier is badly crevassed at a certain spot, but do not plot it as, once negotiated, it is of no consequence to them. A later party attempts to ascend the glacier and wastes the same time in re-discovering the best route. The best survey is, therefore, one which shows as much detail as possible in the widest strip along the route, and this cannot be done to the best advantage by theodolite or sextant alone. It is astonishing how much detail is unconsciously left to memory and what tricks memory will play when months later the map is in preparation. What is required is some graphical method by which the detail can be plotted on the map in the field as a direct observation. This requirement is fulfilled by the plane table, by which at one and the same time we can make a rough triangulation and fill in the detail on the spot.

A further use of the plane table of peculiar interest to polar travellers must be mentioned here. In a region where food depots have to be found and picked up, where outward routes must be followed on the return journey, and where glaciers must be traversed along special tracks, it is obviously of the highest importance for a returning party to know at any time where they are with regard to their former route. In fact, the safety of the party will sometimes depend on their ability to do so quickly and accurately. The food depots are usually placed at points which can be easily found, but the outward route must curve in and out amongst crevassed areas which are seen and avoided at the time. For instance, the route up the long Beardmore Glacier on the Polar journey was a somewhat intricate one, the result of a careful choice, avoiding bad places which could be seen from below and not from above. On the return journey from the Pole each party was delayed, sometimes very seriously, by losing the route and stumbling into bad areas. A valuable feature of plane table surveying is that at any time the position of the table can be found by resection from known points, and, if merely a skeleton survey of the outward journey were made, a short halt to make a resection on the journey down would give the parties their position. The method was used by a party on another glacier and found of use in less urgent circumstances, so arrangements were made for its adoption on the Beardmore for the next journey in search of the Pole Party, a journey which, however, did not take us as far as the glacier.

There is another minor convenience in having a graphical survey, which will particularly appeal to those who are acquainted with the difficulty of judging distance in polar regions. The survey being to scale, the distance to any point that is visible can be roughly found in a few minutes. On the coastal survey it became the regular custom to consult the sheet to see how far any feature was away before attempting to set out to walk to it, a practice which prevented many disappointments. It should be mentioned that appearances can be so misleading there that men have been known to set off to visit a hill or cape in an afternoon walk, which was really thirty miles away, under the impression that it was only six or eight miles.*

For continuous and rapid journeys the method suggested is to use a light theodolite as indicated above and to keep a plane table in constant use. The sheets need not be continuous nor need they depend on any original base line. New sheets may be commenced at any time on a base line given by the sledgemeter, or without a measured base line at all, using some arbitrary scale and determining its value afterwards. The theodolite observer would fix the distant points and take occasional astronomical observations, while the plane tabler would be responsible for all the detail and aim at sufficient accuracy in his principal points to enable him to resect with certainty. When the final chart is prepared, the plane table sheets would be fitted to the framework formed by the points from the theodolite survey. It is, in fact, the ordinary method of rapid topographic survey in temperate regions which seems somehow to have been neglected in polar work.

We will now pass on to the special requirements of a plane tabler under these conditions and then to the somewhat unusual methods which they impose upon him.

The survey equipment which was taken down did not include a plane table, and it had to be improvised out of whatever could be got. It was, therefore, entirely home-made and consisted of an ordinary drawing board 13½ by 17 inches in size, mounted on a stout camera tripod. The latter was fitted with a broad top 9 inches in diameter, covered with velvet, and the board was clamped to it by a heavy screw with large wings passing through the centre of the tripod top. The alidade was a plain 15-inch wooden rule, stiffened by a brass strip screwed to its lower surface, and the sights were fashioned out of two long brass hinges screwed to the rule and folding down when not in use. The foresight was at first fitted with a fine brass wire soldered to the hinge, but later on this was replaced by fine thread which was very easily renewed. An ordinary theodolite trough compass was carried but was of little use. The whole apparatus except the tripod was packed into a large double pocket of green canvas, the table in one pocket, spare sheets in the other, while the smaller accessories fitted into smaller pockets on the outside. The pockets were made so as to close tightly enough to exclude drift snow, and the fastenings were by lanyards, not buttons. The whole was arranged to fit on the after part of the sledge behind the instrument box, where it was safe from injury except from ice pinnacles or careless sledge packers. During the day the table was generally left attached to the tripod and carried on top of the sledge, thus being available for rapid setting up at short halts.

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* This is far from being an isolated case. The writer has vivid memories of a march when at 6 p.m. the leader announced he would camp at a rock apparently half a mile away. At 9.30 p.m. a very tired party gave up pursuit of the rock with many remarks about optical illusions and the obstinacy of leaders.

The instrument as described was in constant use for two summers and came through without harm or much alteration in design, but there were naturally many faults in such an impromptu adaptation of parts. The clamping arrangement was particularly faulty, the tripod was rather light, and the board was inclined to warp.

For polar work, as for most rough surveys elsewhere, lightness and steadiness have to be insisted upon at the expense of other qualities. An ordinary large pattern table is very suitable for work near the base, but for sledging one of special construction is needed for which the following specifications are suggested as a basis upon which to build.

The tripod is the most important item. As far as ease of transport is concerned there is no particular advantage in having a folding tripod, since the length of an object is of little consequence in packing a sledge. The feet of the tripod legs should have aluminium lugs attached to prevent their sinking deeply into a snow surface, and the wood should be ash. The turntable arrangement is important ; it must have as few turn-screws as possible, and these should have large heads and be covered with wash leather to save the fingers in cold weather. A fine adjustment screw is not necessary for the type of work contemplated. The simplest arrangement is to have a turntable permanently screwed to the table with its clamping screw attached, the whole fitting on the tripod with a single large central screw, or by pins on the legs of the tripod. The Johnson head, as used in the United States Geological survey, would be admirable. The table should be small enough to be light and handy, remembering that it has to be carried into somewhat inaccessible places, and should not have a side longer than 20 inches.

The sight rule or alidade needs special mention, and the one mentioned above limited the work considerably by its shortcomings. The objects sighted are rarely so distant or so minute as to need a telescopic alidade, yet such is desirable for other reasons. Except on the rare occasions when the theodolite was set up close to the table, all altitudes had to be taken separately with a small Abney level, thus doubling the time for many of the rays. Again, the table was constantly in rugged country when the sights were highly inclined and clumsy plumb-bob methods of sighting had to be used. These two considerations became of such importance that an attempt was made to mount the Abney level on the sight rule but was unsuccessful. What is required, therefore, is a light sight rule with the usual sight vanes but with a fitting for a light telescope with graduated arc for taking altitudes.* Such a combination could be made at small cost by any instrument maker. Even more useful would be an alidade combined with a clinometer of the Indian Survey type.

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* A new form of sight rule, depending upon a prism instead of sight-vanes, now being produced by Casella, would be very suitable.

The ordinary accessories for plane table work need not be specified, but one or two unusual ones need a brief mention. A light cover, which need not be waterproof, is needed for the table, for even in fine weather very fine crystals of ice fall on the table and are difficult to brush off, while, if they happen to thaw, the paper becomes coated with a glaze which cannot be got rid of easily. A piece of emery cloth glued to the under surface of the table or the tripod will save many cold fingers when the pencil needs sharpening. In really cold weather the rubber must be kept in a fairly warm pocket or it becomes hard and useless; it should be tied to the pocket with a long string, otherwise it is very easily dropped or lost by numbed fingers. Protection for the hands is somewhat of a problem. Ordinary dogskin " mitts " are too clumsy and thin leather gloves are too cold. Perhaps the best compromise is a pair of loose mitts of catskin, fur outside, with places for the thumb and first finger, but even with them the ruling of a large number of rays in a breeze is a chilly business. For inking in the day's work, liquid ink is, of course, impossible, and solid Indian ink is taken. A small amount of snow is melted by the breath in a watch glass and the ink rubbed in it. In such a small quantity it readily freezes again but is easily re-melted by the breath, and very little time is really wasted over that difficulty.

The problem of what is the most suitable type of paper was settled by obtaining sheets of Bristol Board from the artist of the expedition and this gave great satisfaction. The objection that it cannot be rolled up did not apply, since the spare sheets were kept in a pocket which lay flat against the board itself when packed. It had to be fastened to the table with drawing pins, which projected a little but were not any great hindrance, and, since the sheets had to be frequently changed, any method of pasting would have been out of the question apart from the difficulty. The variations in humidity are not great in such climates, and such as there were had no effect on the Bristol Board beyond buckling it in one large curve. It is hardly necessary to add that any distortion caused by expansion is negligible, having regard to the low order of accuracy of the work.

A somewhat unusual method of using the plane table on the ship was given a trial, and though the opportunity did not occur again, the results were encouraging, and the method is perhaps worth recording. It has since been discovered that what must have been a somewhat similar method was used as long ago as Nathorst's Expedition in the survey of the Franz Josef Fjord in East Greenland.

The table is mounted on its tripod somewhere on the middle line of the ship, preferably close to the standard compass and high enough to have an unrestricted view. It is placed in such a way that the proposed survey of the next few hours will fit on the sheet and is then clamped. A firm pencil line is drawn in the direction of the ship's head, which may be called the fore-and-aft line, and this becomes the reference line for orientation. Whenever the ship alters course, the angle of turn is obtained from the officer of the watch or from the compass, and the plane table is swung through that angle and clamped. A new fore-and-aft line is then drawn. The orientation, therefore, depends almost entirely on the compass. The general procedure is then as follows :—A time scale is constructed of minutes, the scale depending, of course, on distance from the coast, etc. At the first station the time is noted and written opposite the station, and the necessary rays are quickly drawn. When more rays are to be drawn, the time which has elapsed gives the new position, but as soon as some points have been fixed, there is a check on both the time scale and the course by resecting from fixed points. Changes in the ship's course and rate introduce complications, but these are easily dealt with, especially if the officer of the watch warns the plane tabler of them before they take place. After the turn has been made, it is advisable to plot the first station on the new fore-and-aft line by resection and start a time scale again from that point. It is obvious that such a method demands a steady ship, a straight course and an even rate, but those are just the conditions which frequently occur in places like the Ross Sea. The real hindrance is pack ice, which generally would prevent effectual use of the method.

The sheets when finished will provide the detail to add to the chart based on the astronomical fixes. A small calculation will give the approximate errors in such a method, and by a suitable choice of scale they become negligible over small areas. For instance, if the ship is moving at 6 knots and the coast-line is 2 miles away, an error of one minute in the time scale will produce an error of 3° in rays to the coast, involving errors of 200 yards for any one point. Such an error would be gladly passed by most nautical surveyors under those conditions.

Two other methods are suggested by experience. The first is the use of the theodolite as a tacheometer. It is frequently necessary to make moderately accurate measurements of distance for which the sledgemeter is not suitable or convenient. With bamboos, or even the ski-sticks painted black and white in suitable divisions as staffs, a great many scientific measurements, if not actual survey work, could be done.

The second is the use of the hand level, already referred to, for the many small levelling operations that are specially required in the study of ice forms.

We turn now to the brief consideration of a very different type of surveying.

GEODETIC SURVEYS.

There can be little difference of opinion as to the utility of the measurement of an arc of the meridian in southern latitudes, a region so far removed from all other geodetic measurements. The climate in Polar regions is usually regarded as too severe to allow of the more precise instrumental methods of surveying. This is a mistaken view, for in the height of summer with its clear days, reasonable temperatures and moderate winds, the conditions of climate are no worse than in many temperate regions, Further, the distribution of the land masses in a meridional direction, the frequent occurrence of suitable peaks, and lastly the existence of several off-shore islands make the coast of South Victoria Land particularly suitable for geodetic investigation. Indeed, many of the difficulties which attended the measurement of an arc in Spitsbergen, such as foggy weather and inaccessibility, would be avoided.

Since McMurdo Sound is so well known and is already furnished with several huts, it offers itself as the most suitable locality for winter quarters and the preliminary reconnaissance and base measurement. If a fresh winter quarters were to be selected, its best position would be on the western side of the Sound, since that will never be cut off by open water from the rest of the area, as is the west coast of Ross Island.

For the position of the base, several localities offer themselves. The south of McMurdo Sound is closed by a permanent sheet of land ice which offers in parts an excellent surface over which to make precise measurements ; moreover, the position of the Dailey Islands, entangled in the sheet and in the centre of the Sound, offers great possibilities for the ends of the base. The McMurdo Sheet, however, has a slow movement in a northerly direction, and at first sight this excludes its use. On the other hand, the movement being very slow, probably less than one foot a week, it would not be difficult to eliminate the error from that cause if (1) the base measurement were carried out within a short period of time, and (2) its direction were chosen at right angles to that of the movement. The extension from such a base would be extremely simple, although it would involve some sledging over rough ice. There are other possible situations for the base which closer examination might prove to be even more adaptable to the purpose, and, in any case, the choice of the base would be merely a question of careful examination on the ground.

From the situation of McMurdo Sound, it may be seen that the main triangulation could then be run in both a northerly and southerly direction. (*See* Fig. 21.) To the south, however, it is limited by the curious ridge of Minna Bluff in Lat. 78° 40′. To extend it further in that direction would mean prolonged journeys over difficult and unknown areas. Towards the north the extension is at first very simple. Aiming at very large triangles with sides up to 50 or 80 miles in length, the triangulation would leave the Sound on a base extending from Abbott's Peak on the north side of Erebus to one of the 3,000 feet peaks in the neighbourhood of Dry Valley. The next points for the framework would then be Beaufort Island to the north of Cape Bird and one of the 4,000 feet peaks at Granite Harbour. From each of these the summit of Franklin Island would be visible for the next point, but it would probably be necessary to swing the general direction of the triangulation somewhat to the west, since there is no other island available off the coast until we reach Coulman Island, 180 miles north. The framework would then be continued with rather smaller triangles along the coast from the Nordenskiold Glacier Tongue to the neighbourhood of Mount Melbourne. It may be mentioned that the summit of Mount Melbourne is in Lat. 74° 30′ S., so that thus far we have an arc of 4 degrees, and we may now examine what such a measurement would entail in the way of journeys. It may be said at once that the only uncertain factor in visiting these stations is the state of the ice in the summer round Franklin and Beaufort Islands, but since parties have landed on both of them, nothing but a certain amount of patience can be required. The points along the coast would be visited by sledge parties, preferably with dog transport, passing up the coast in the spring and summer, but on account of the short season it would probably be advisable at a later stage to land a party with a hut at Evans Coves in Lat. 75°.

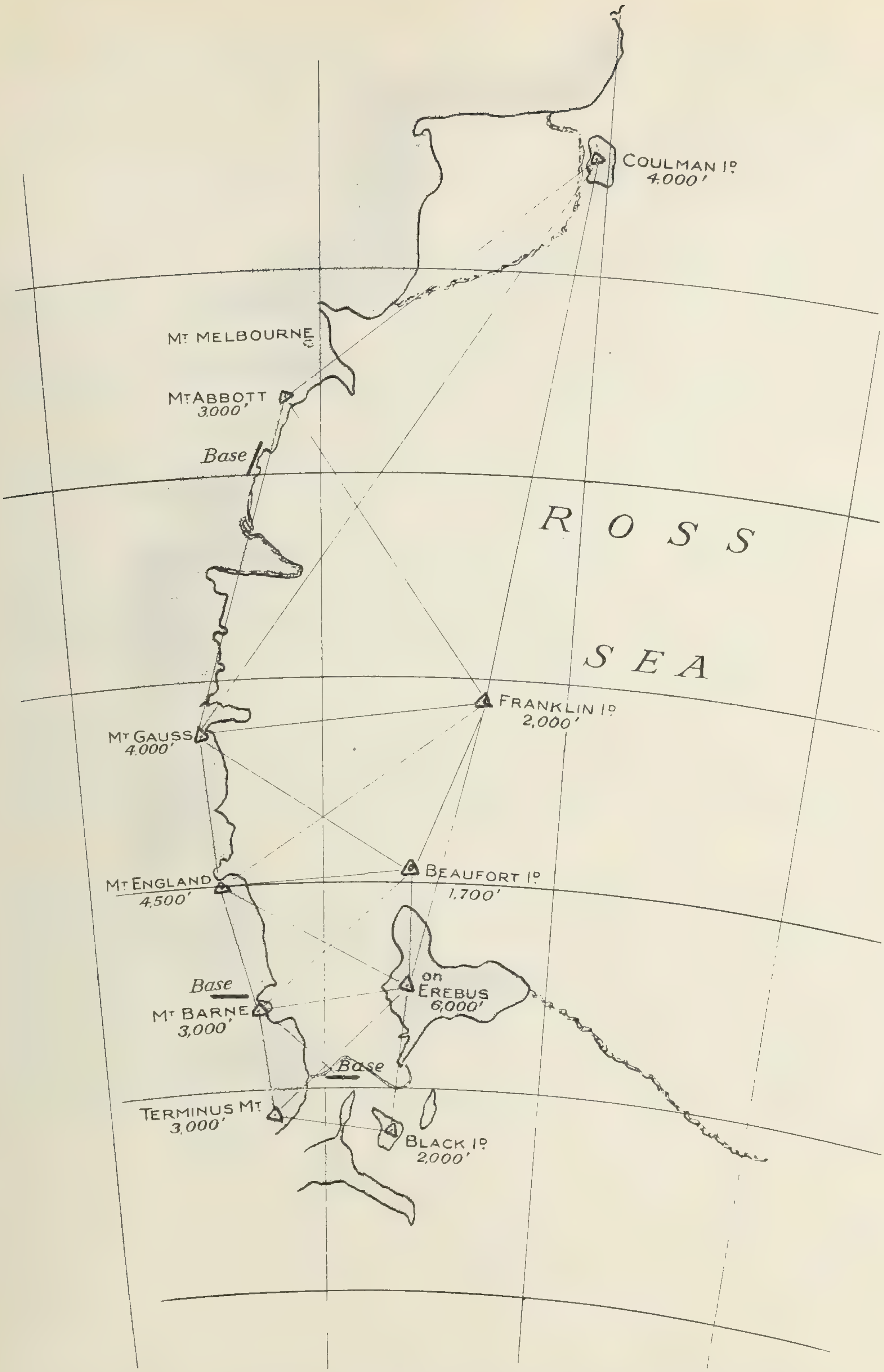


Fig. 21.—Sketch map to illustrate the possibility of Triangulation along the Victoria Land Coast.

It is to be feared that these plans will appear extravagant and optimistic, especially to those who have personal knowledge of the many difficulties in work of geodetic accuracy, but one or two advantages in the local conditions must not be missed. Accounts of geodetic measurements bristle with difficulties due to atmospheric causes, chiefly haze. Now the clearness of the Antarctic atmosphere is almost beyond belief. During the ascent of Mount Erebus an azimuth was taken to Mount Melbourne, distant nearly 200 miles, with the theodolite, its shape being recognised with the naked eye. At a height of 10,000 feet the 7,000-feet mountain behind Cape Jones came into view, distant some 300 miles, refracted up but perfectly distinct. Again, the ship, when against a background of pack ice, was commonly seen by the naked eye at a distance of 30 miles. With such an atmosphere little loss of time from the presence of haze need be feared.

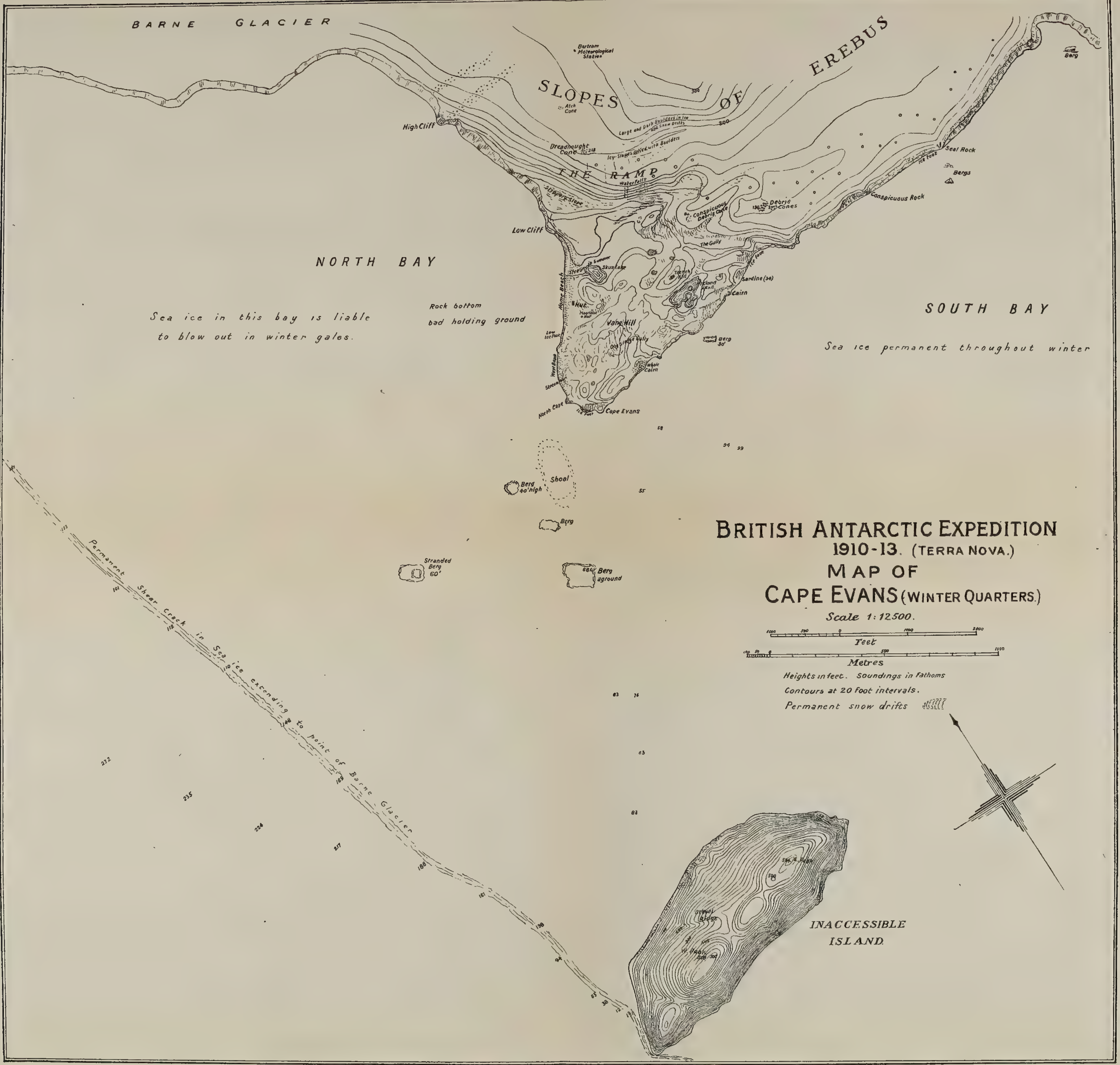
The uncertainties of refraction are a much more real difficulty, especially with so many rays passing across water.

The work of reconnaissance in such a region is on the whole simpler than in many other countries, the clear atmosphere and comparatively smooth travelling between points being all in favour of quick work.

Transport, even of the heavy apparatus and material inseparable from such precise work, would be, as elsewhere, merely a matter of money and careful organisation. For the land and ice journeys dog-teams and for the sea journeys a sloop with auxiliary power, or the ship itself, would probably be the best means of travel. Small wireless sets would provide the inter-communication.

The number of men required, even if a number of stations had to be occupied simultaneously for signalling purposes, would not be greater than those of a fair-sized expedition. Estimates of the time required must be exceedingly vague, but it is thought that three summers' work might prove sufficient, if sufficient observers were available.

The writer feels the greatest diffidence in publishing even the outlines of a scheme apparently so far removed from even serious discussion, much less practical achievement. He is induced to do so only because of the manifestly incorrect ideas prevailing about the possibilities of such work under polar conditions and in the endeavour to prove that such difficulties as there would be are those of organisation and expense rather than of climate. Should Ross Sea become a centre for whaling, even on a moderate scale, the expense would be greatly reduced, and the work could be spread over a longer time. With that apology the writer leaves the matter to mature or to decay as it may deserve.



BRITISH ANTARCTIC EXPEDITION
1910-13. (TERRA NOVA.)
MAP OF
CAPE EVANS (WINTER QUARTERS.)

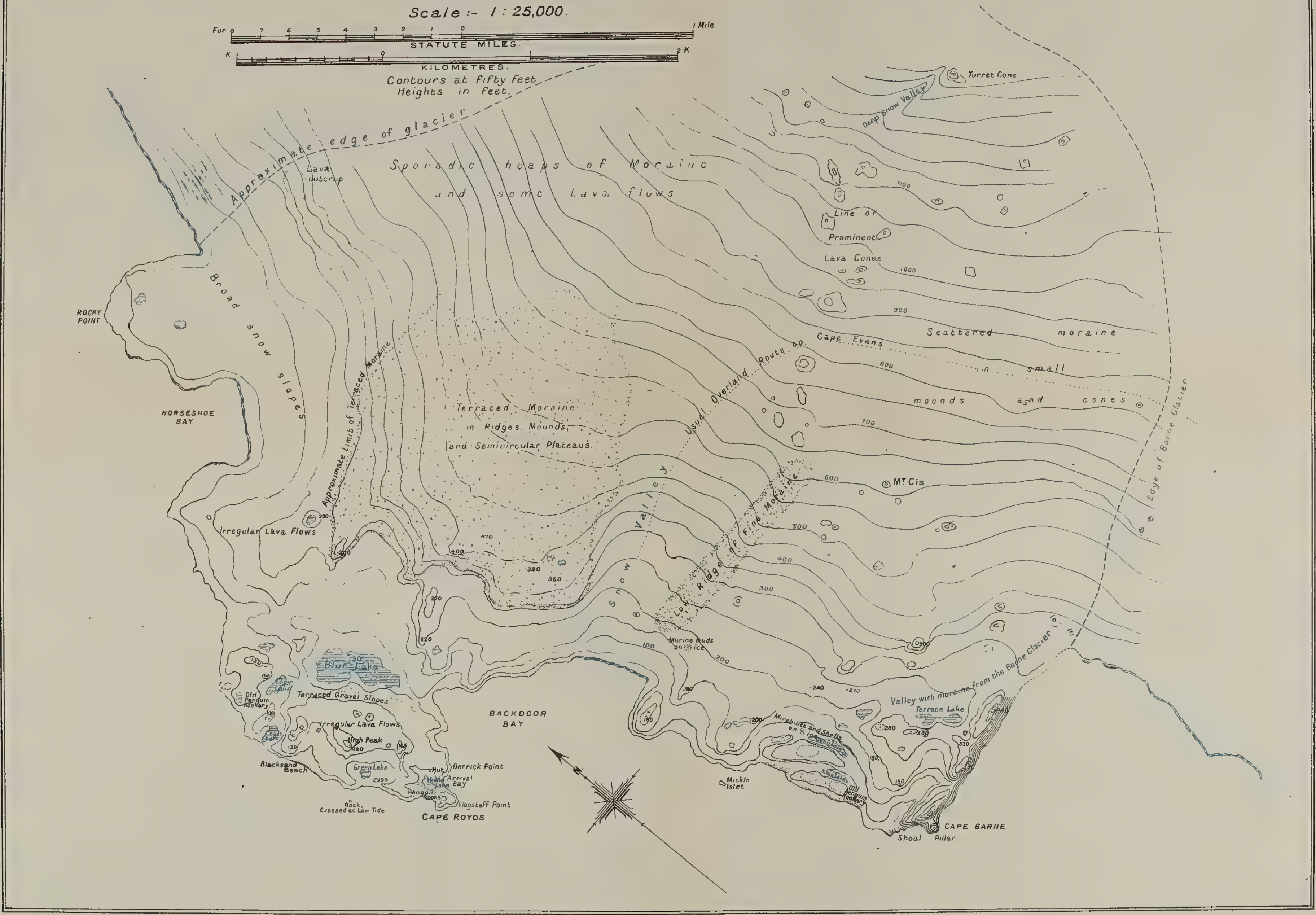
Scale 1: 12500.

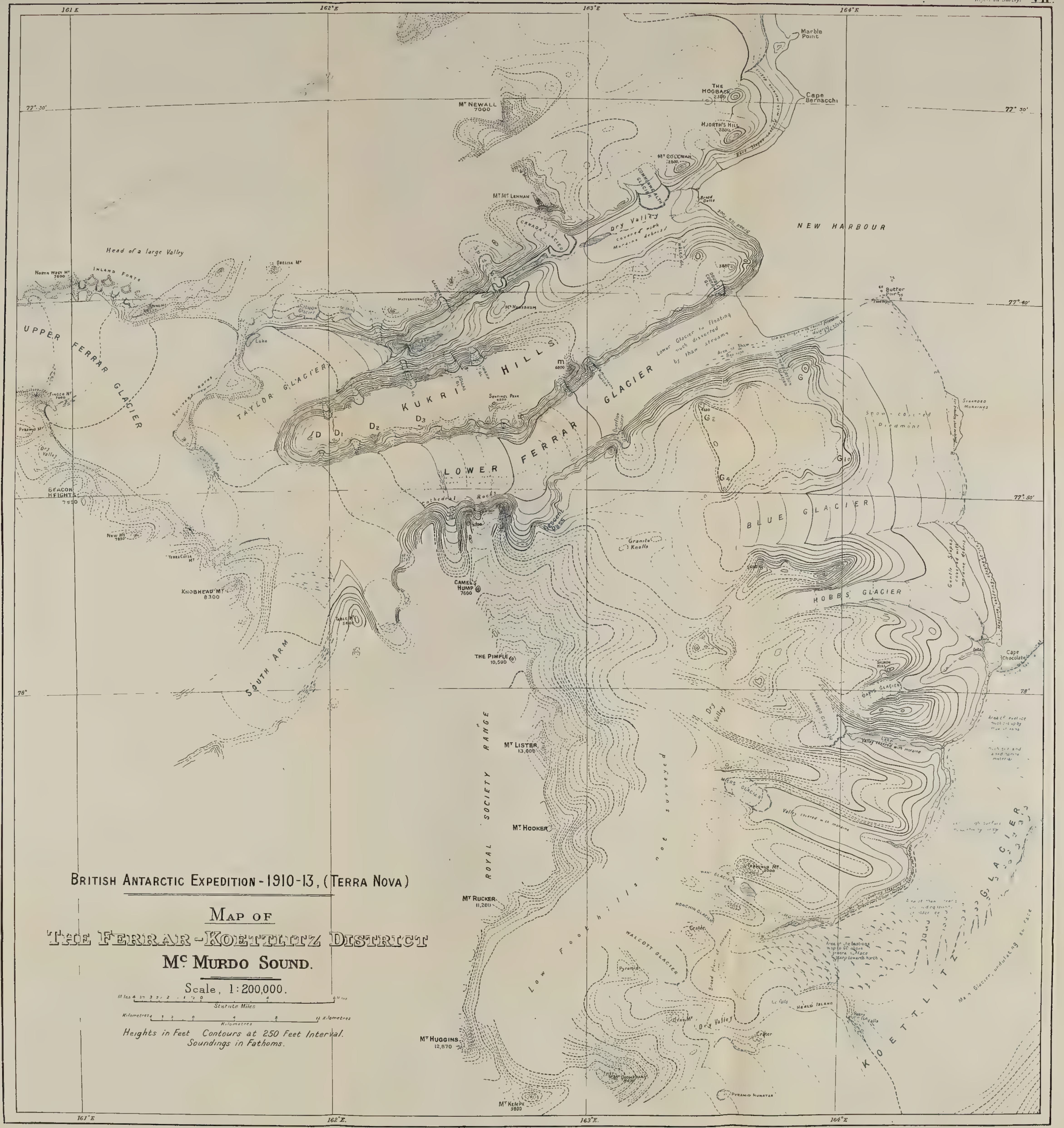
Heights in feet. Soundings in fathoms

Contours at 20 foot intervals.

Permanent snow drifts

BRITISH ANTARCTIC EXPEDITION, 1910-13 (TERRA NOVA)
MAP OF
THE CAPE ROYDS DISTRICT, ROSS ISLAND.



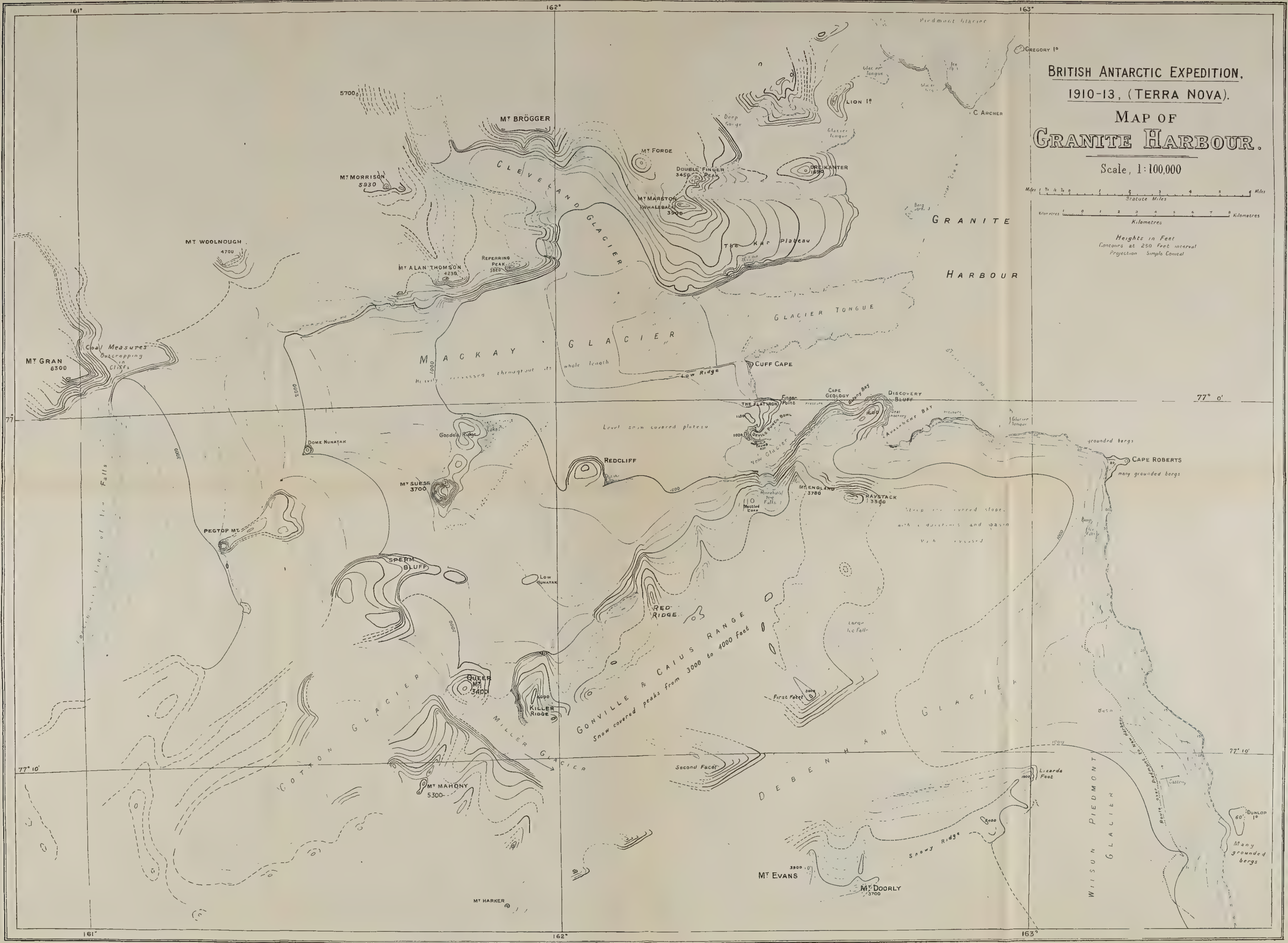


British Antarctic Expedition - 1910-13, (Terra Nova)

Map of
The Ferrar - Koettlitz District
Mc Murdo Sound.

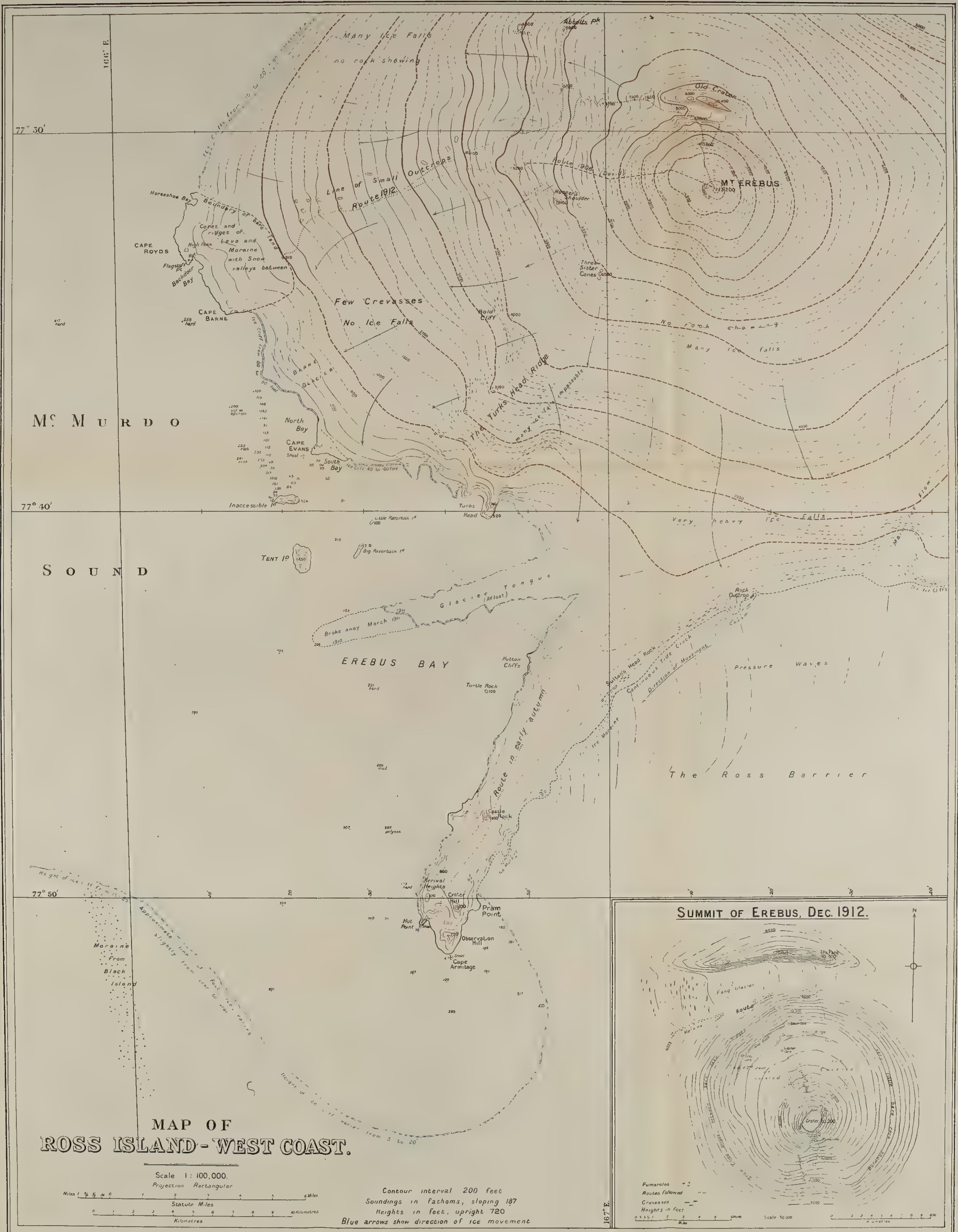
Scale, 1:200,000.

Heights in Feet Contours at 250 Feet Interval.
Soundings in Fathoms.



BRITISH ANTARCTIC EXPEDITION,
1910-13, (TERRA NOVA).
MAP OF
GRANITE HARBOUR.
Scale, 1:100,000

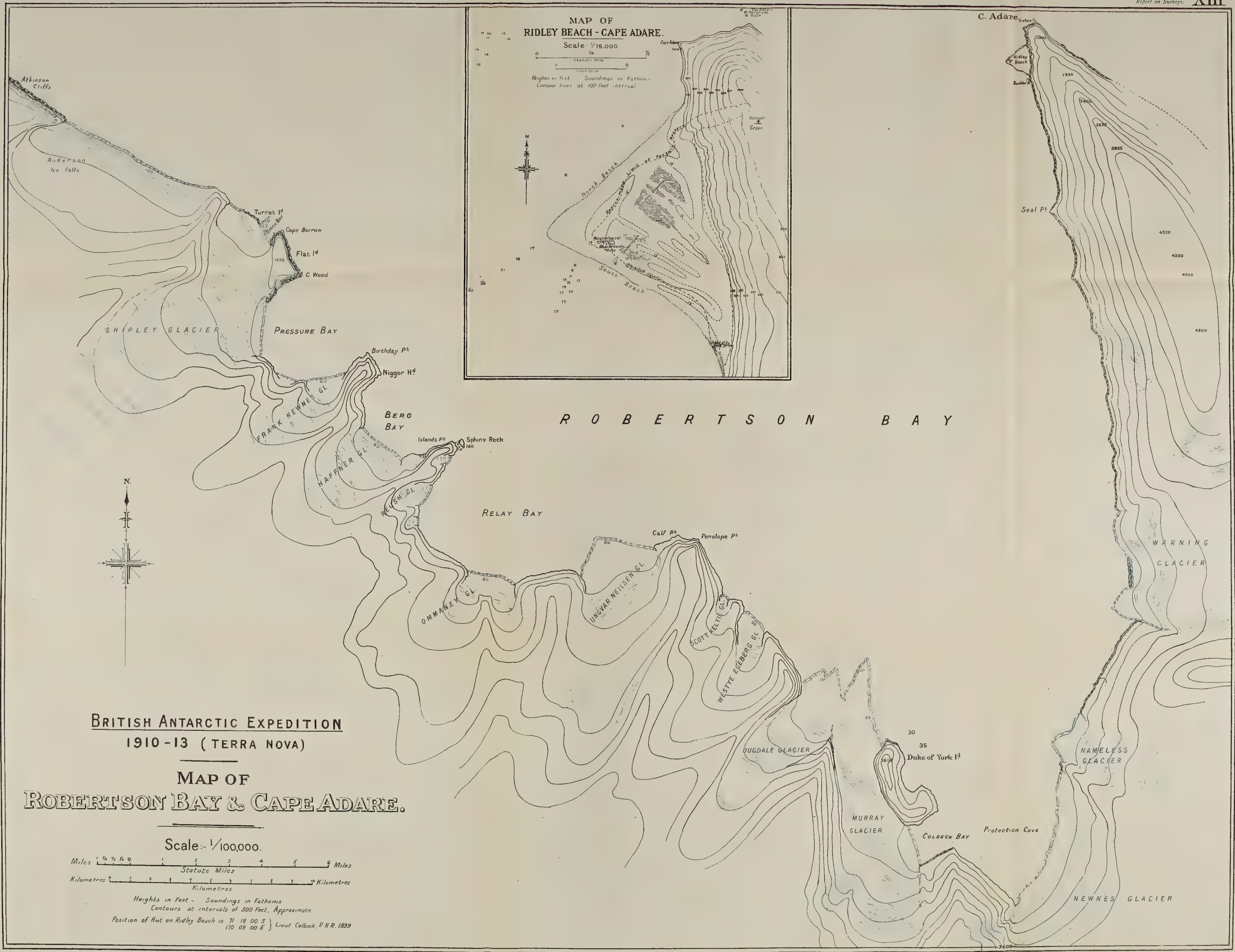
Heights in Feet
Contours at 250 Feet interval
Projection Simple Conical



MAP OF
ROSS ISLAND - WEST COAST.

Scale 1 : 100,000.
Projection Rectangular

Contour interval 200 feet
Soundings in fathoms, sloping 187
Heights in feet, upright 720
Blue arrows show direction of ice movement



BRITISH ANTARCTIC EXPEDITION
1910-13 (TERRA NOVA)

MAP OF
ROBERTSON BAY & CAPE ADARE.

Scale:- 1/100,000.

Heights in Feet - Soundings in Fathoms
Contours at intervals of 500 Feet, Approximate

Position of Hut on Ridley Beach is 71 18 00 S, 170 09 00 E } Lieut Colbeck, R N R. 1899

MAP OF
RIDLEY BEACH - CAPE ADARE.

Scale 1/15.000

Heights in Feet Soundings in Fathoms
Contour lines at 100 Feet interval

BRITISH ANTARCTIC EXPEDITION (TERRA NOVA)

— MAP OF —

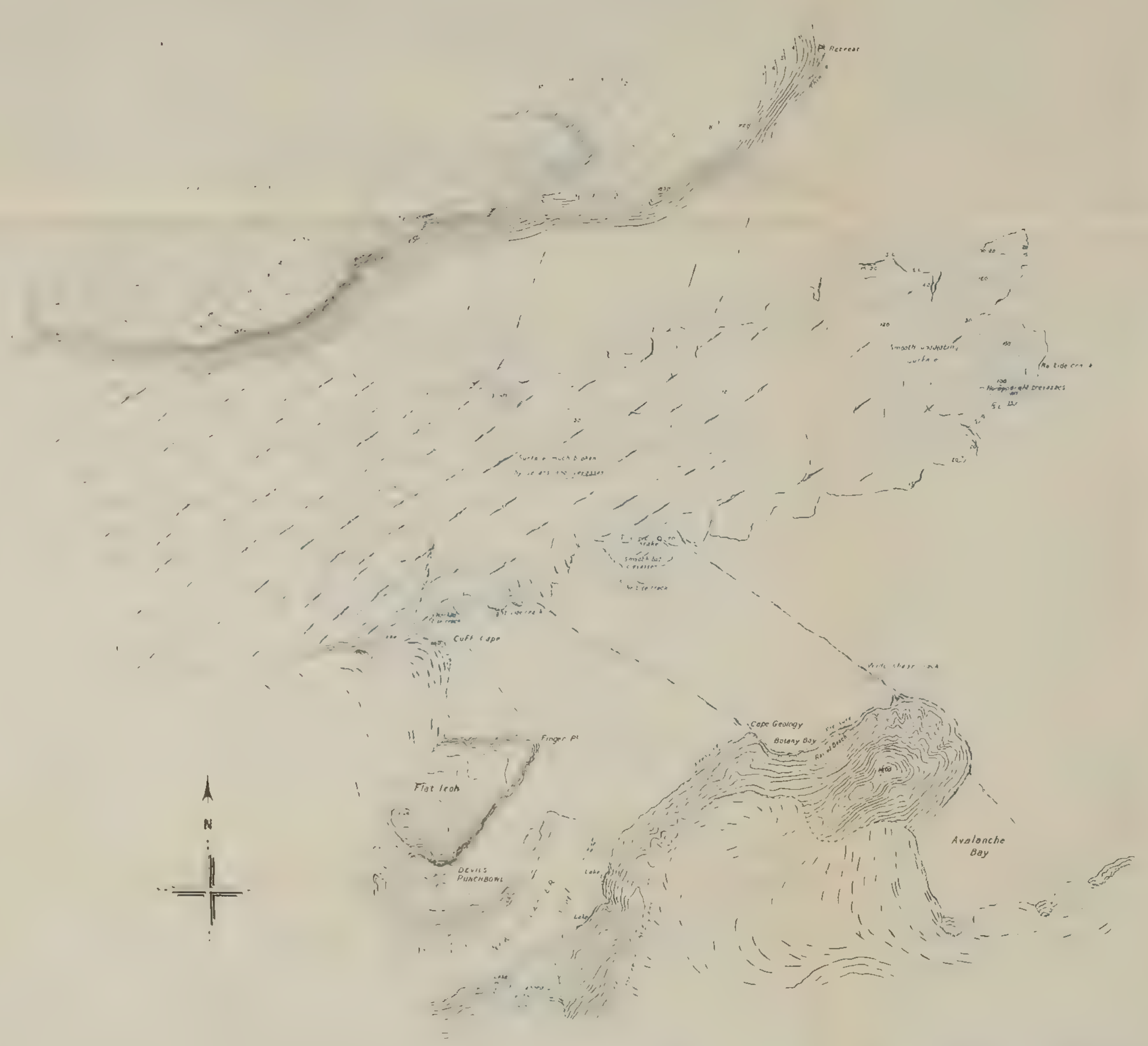
THE INNER HARBOUR, GRANITE HARBOUR.

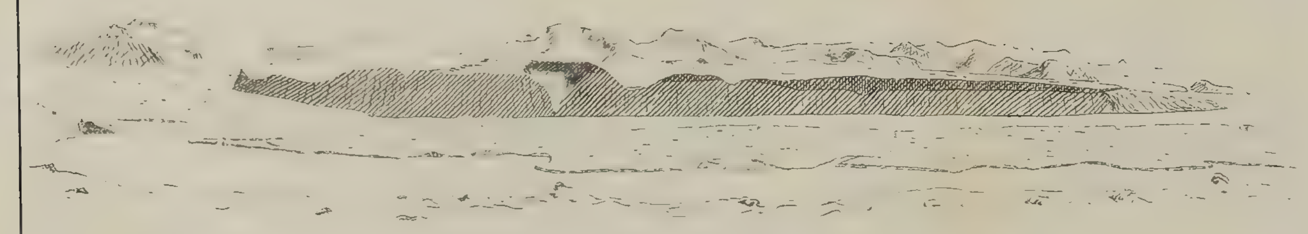
Scale: 1: 50,000

STAT MILES

KILOMETRES

The Form lines on glacier tongue are approximate
Elsewhere contours are at 100 feet interval
Surveyed December 1911
Figures indicate height above Sea level





PANORAMA SKETCH OF GLACIER TONGUE FROM POINT 1,600 ON DISCOVERY BLUFF.

— PLANE TABLE MAP OF —

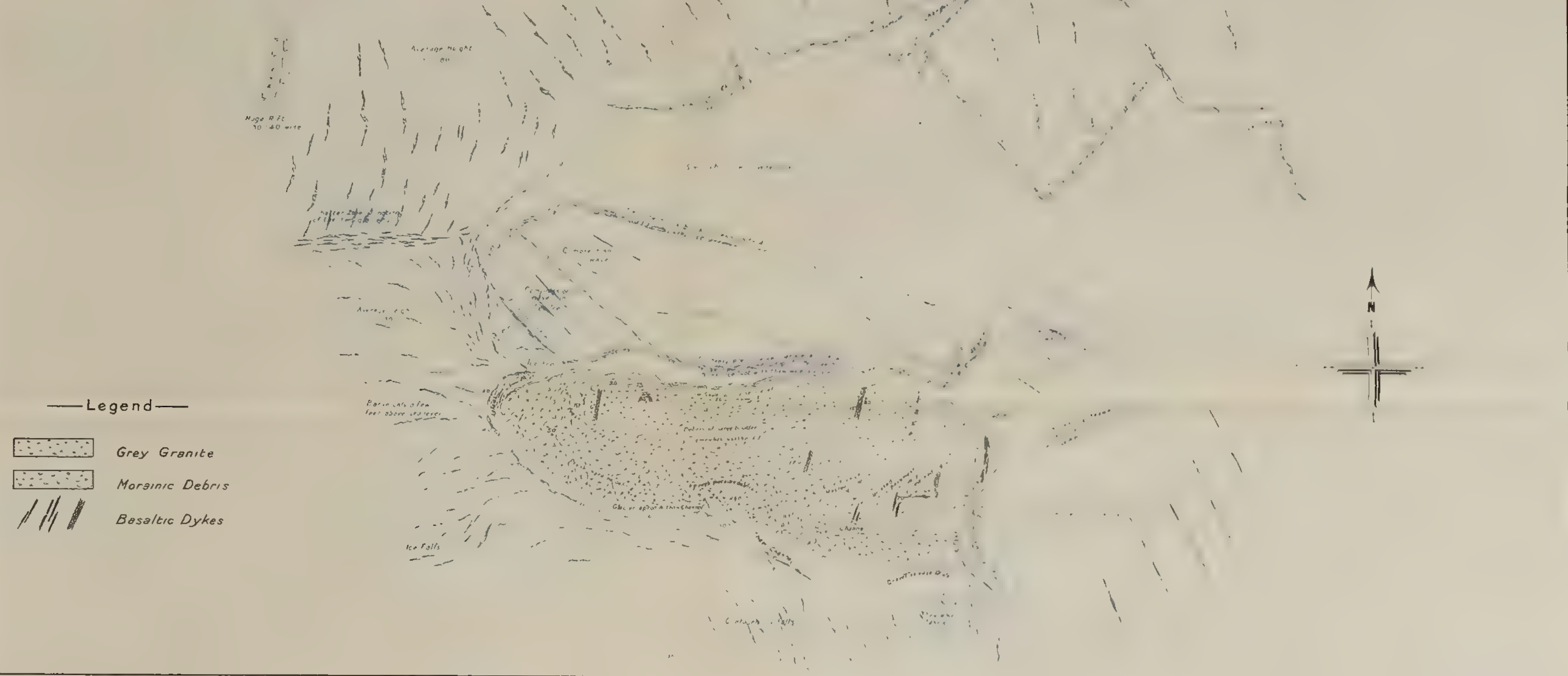
CUFF CAPE, GRANITE HARBOUR.

Scale 1: 6250

YARDS

METRES

Contours at Twenty Feet
Surveyed December, 1911



— PLANE TABLE MAP OF —

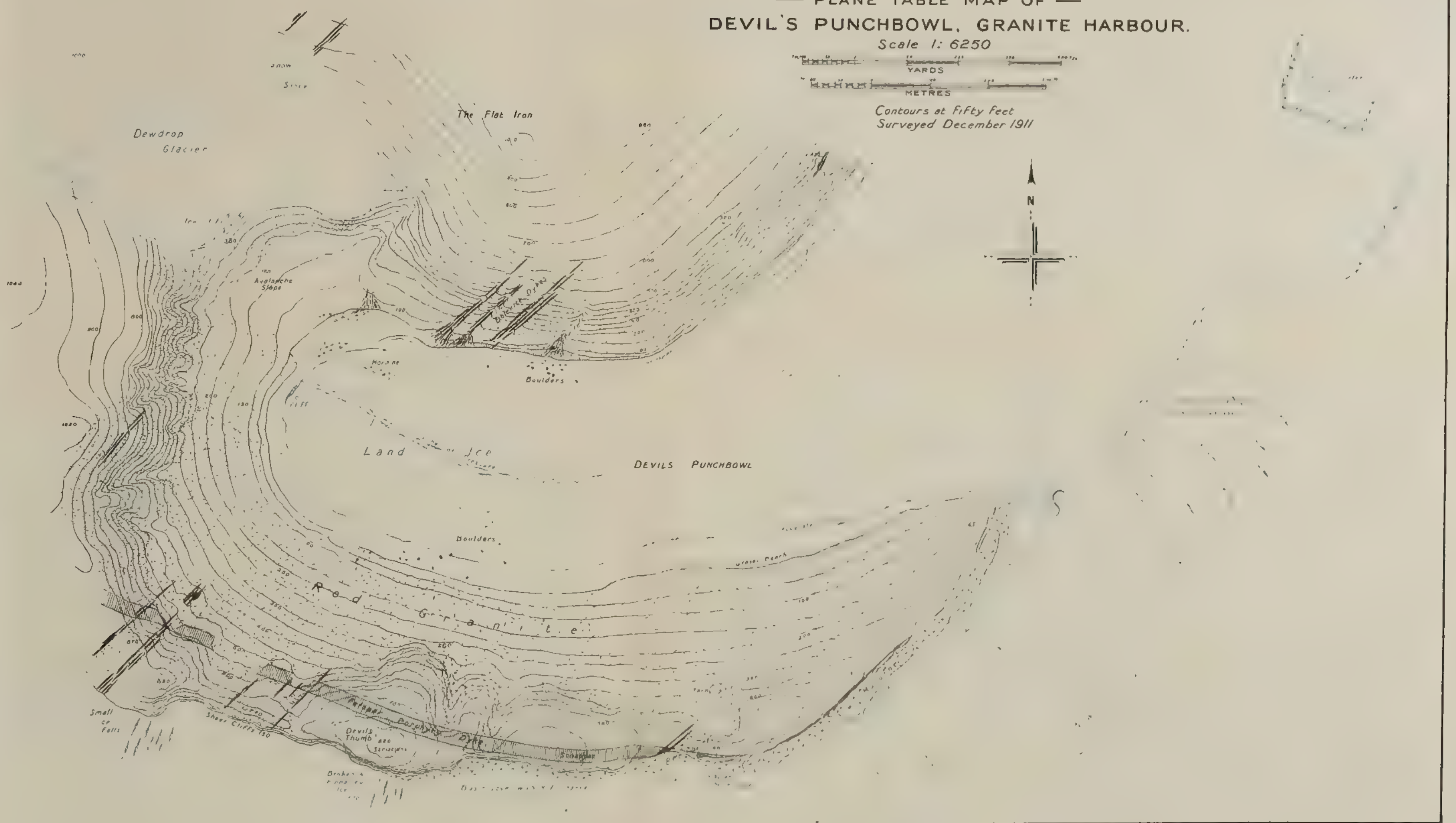
DEVIL'S PUNCHBOWL, GRANITE HARBOUR.

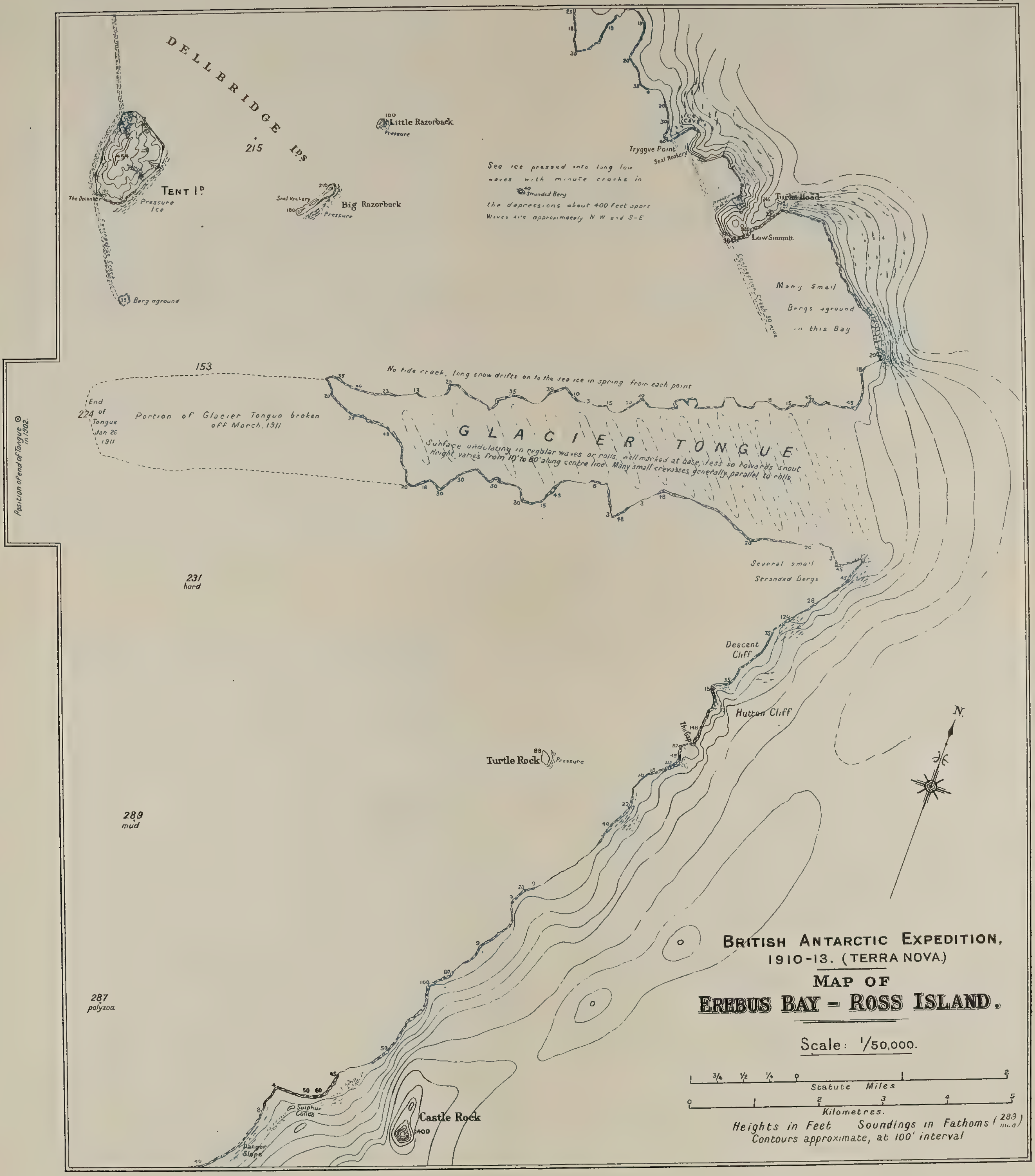
Scale 1: 6250

YARDS

METRES

Contours at Fifty Feet
Surveyed December 1911





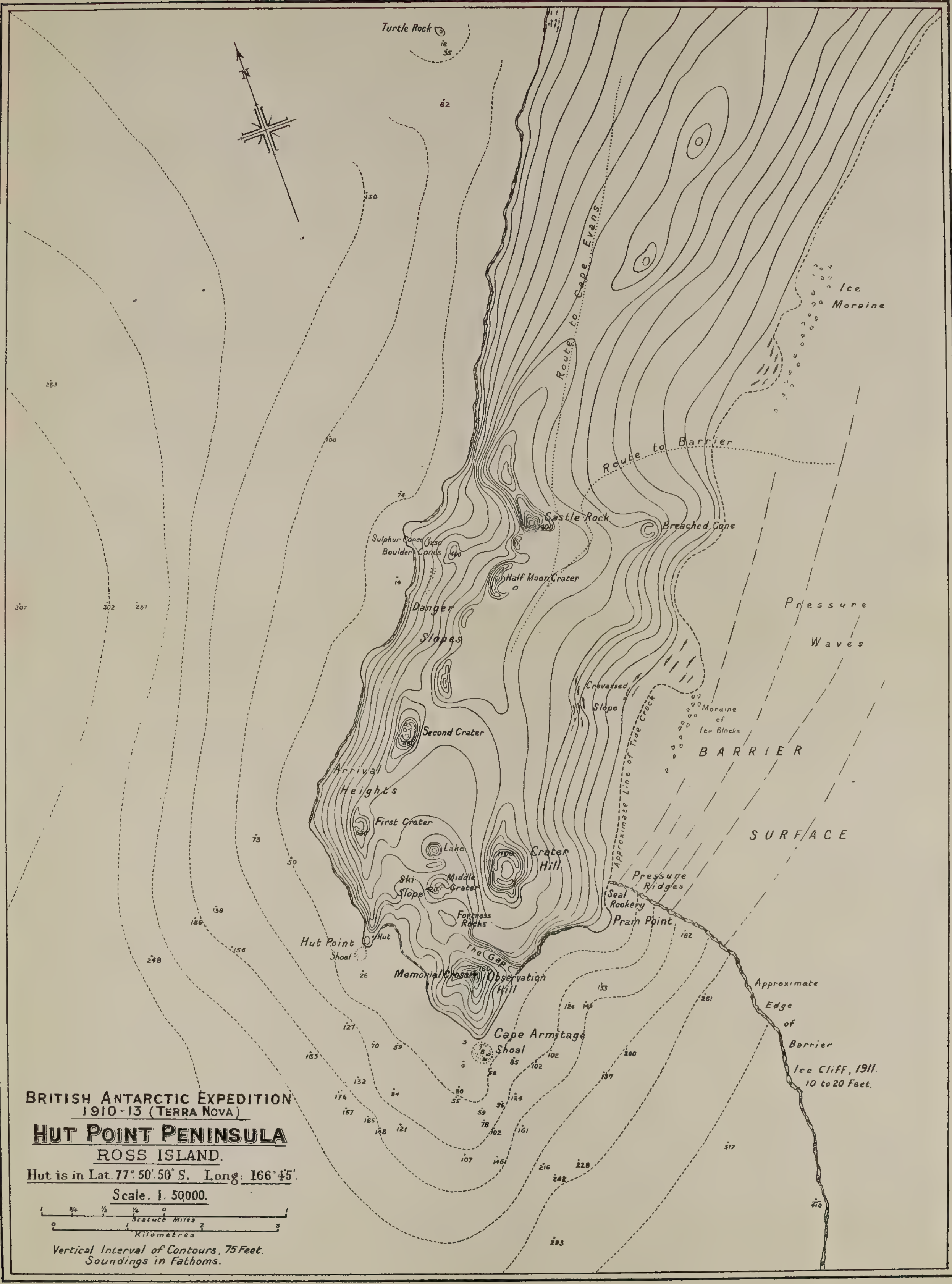
BRITISH ANTARCTIC EXPEDITION,
1910-13. (TERRA NOVA.)

MAP OF
EREBUS BAY – ROSS ISLAND.

Scale: 1/50,000.

Heights in Feet   Soundings in Fathoms (289 mud)
Contours approximate, at 100' interval

DELLBRIDGE IDS
215
Little Razorback
100
Pressure
Tent Id
The Decanter
Pressure Ice
Contraction Crack
Berg aground
35
Big Razorback
Seal Rookery
210
180
Pressure
Sea ice pressed into long low waves with minute cracks in the depressions about 400 feet apart Waves are approximately N W and S-E
Stranded Berg
40
Ice Cave
Tryggve Point
Seal Rookery
Pressure
Turks Head
Low Summit
36
Contraction Crack 30' wide
Many Small Bergs aground in this Bay
153
No tide crack, long snow drifts on to the sea ice in spring from each point
End of Tongue Jan 26 1911
224
Portion of Glacier Tongue broken off March, 1911
Position of end of Tongue ⊙ in 1902.
GLACIER TONGUE
Surface undulating in regular waves or rolls, well marked at base, less so towards snout
Height varies from 10' to 80' along centre line. Many small crevasses generally parallel to rolls
Several small Stranded Bergs
231 hard
Descent Cliff
Hutton Cliff
The Gap
Turtle Rock
99
Pressure
289 mud
287 polyzoa
N.
Sulphur Cones
Danger Slope
Castle Rock
1400
3/4
1/2
1/4
0
1
2
Statute Miles
0
1
2
3
4
5
Kilometres.



BRITISH ANTARCTIC EXPEDITION
1910-13 (TERRA NOVA)

HUT POINT PENINSULA

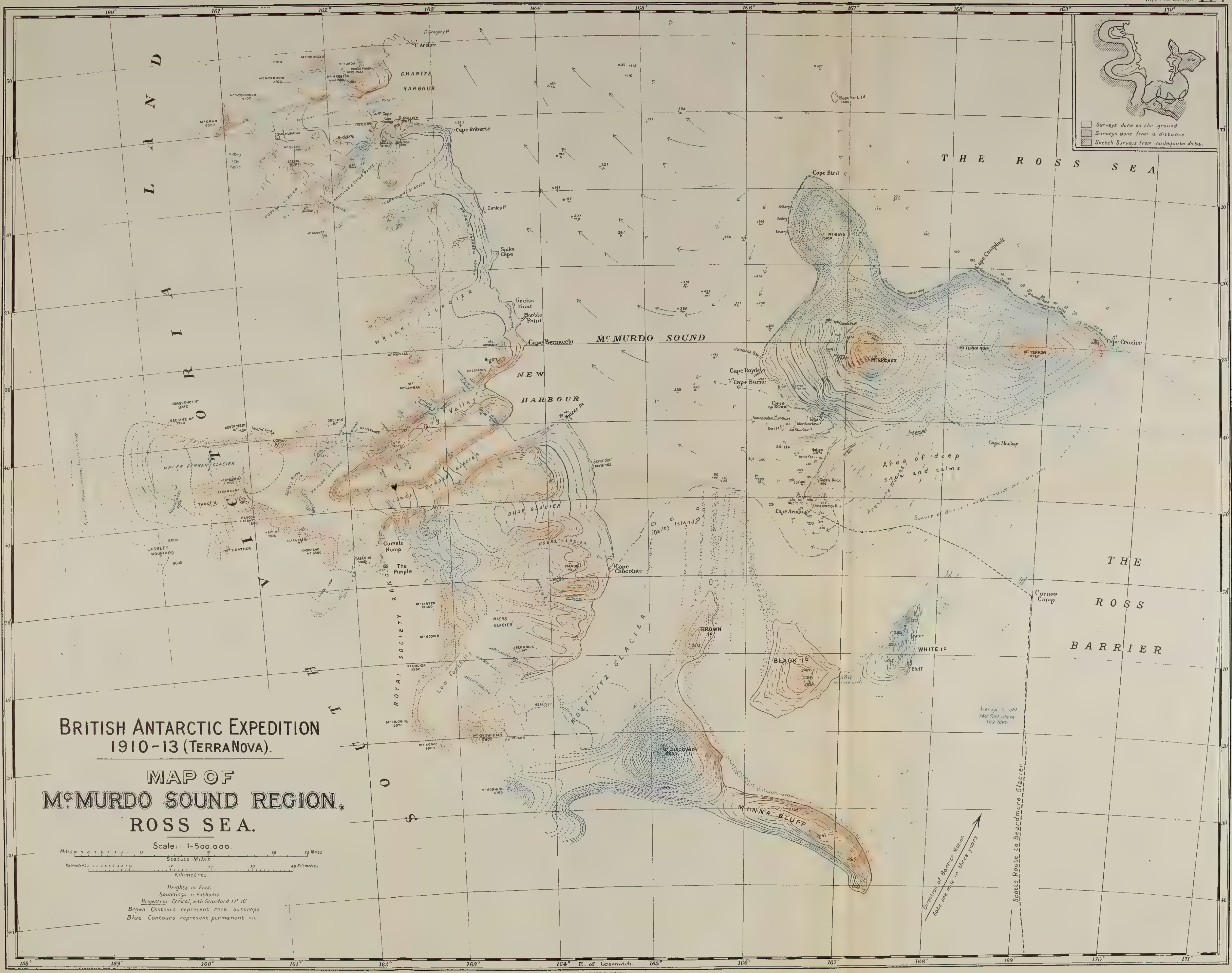
ROSS ISLAND.

Hut is in Lat. 77°. 50'. 50" S. Long: 166° 45'.

Scale. 1. 50,000.

Vertical Interval of Contours, 75 Feet.
Soundings in Fathoms.

HARRISON & SONS LTD. LITH. ST MARTINS LANE, W.C. 2



BRITISH ANTARCTIC EXPEDITION
1910-13 (TERRA NOVA).

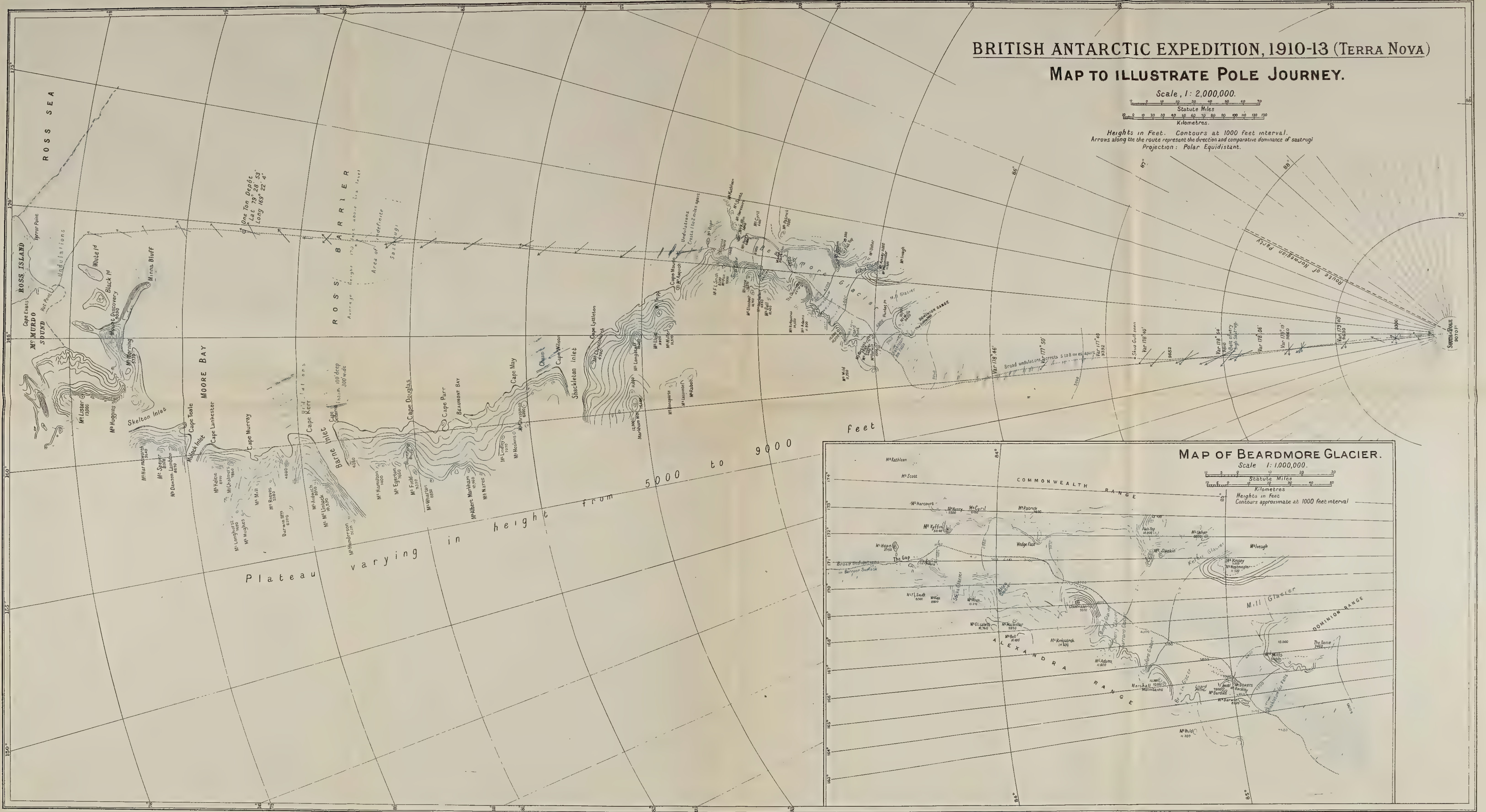
MAP OF
McMURDO SOUND REGION,
ROSS SEA.

Scale:- 1-500,000.

Statute Miles

Kilometres

Heights in Feet
Soundings in Fathoms
Projection Conical, with Standard 77° 30'
Brown Contours represent rock outcrops
Blue Contours represent permanent ice



BRITISH ANTARCTIC EXPEDITION, 1910-13 (TERRA NOVA)

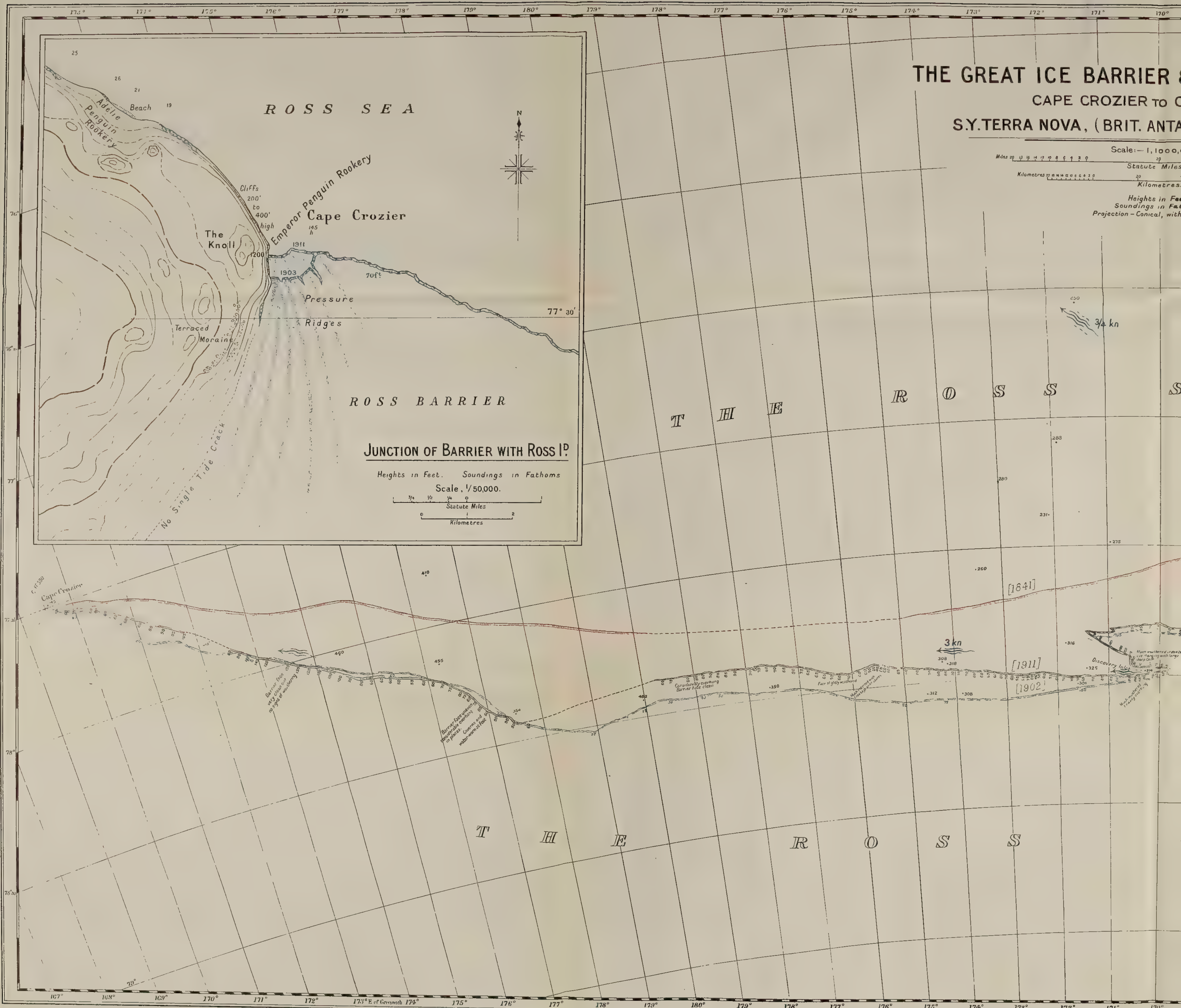
MAP TO ILLUSTRATE POLE JOURNEY.

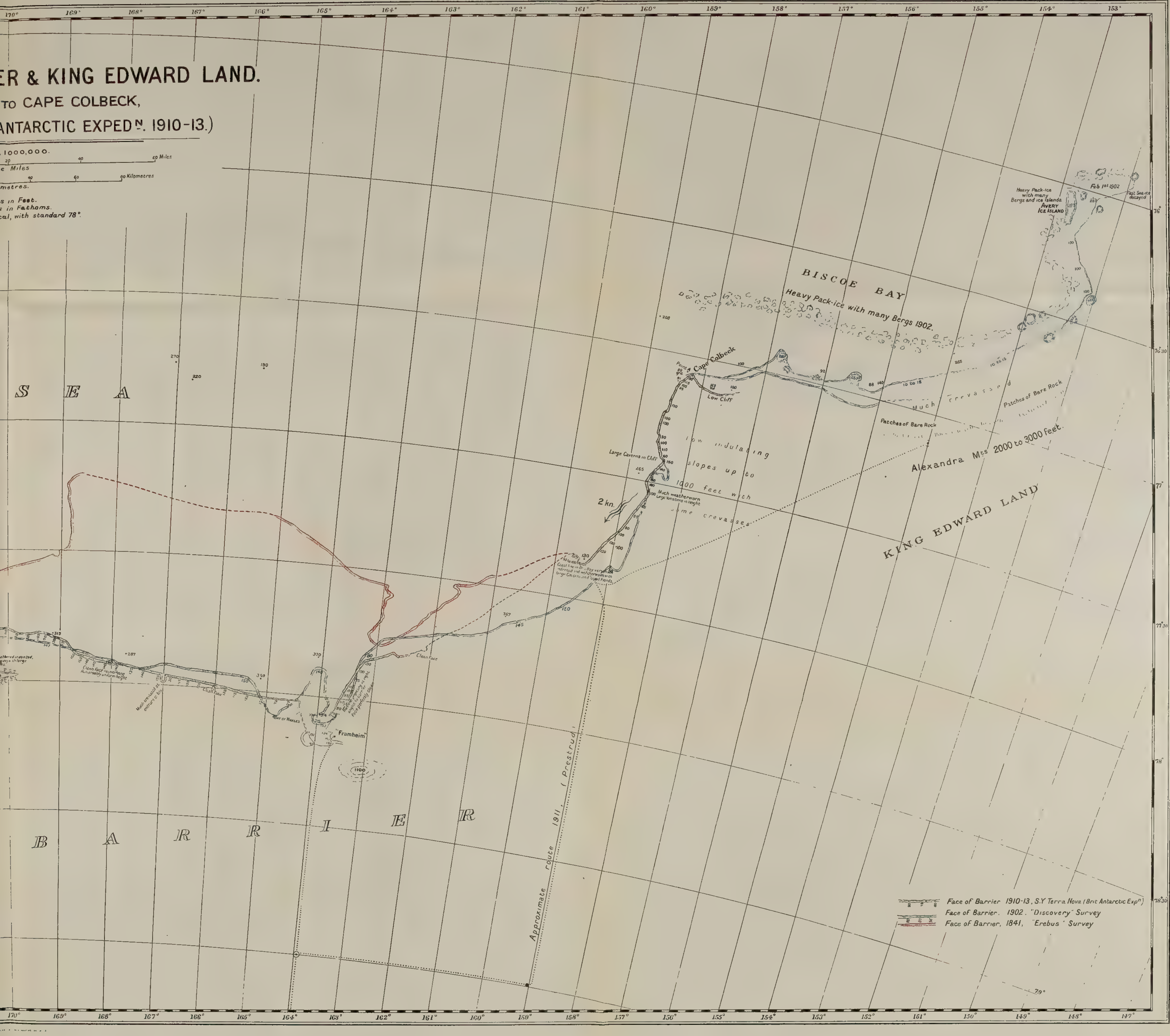
Scale, 1: 2,000,000.

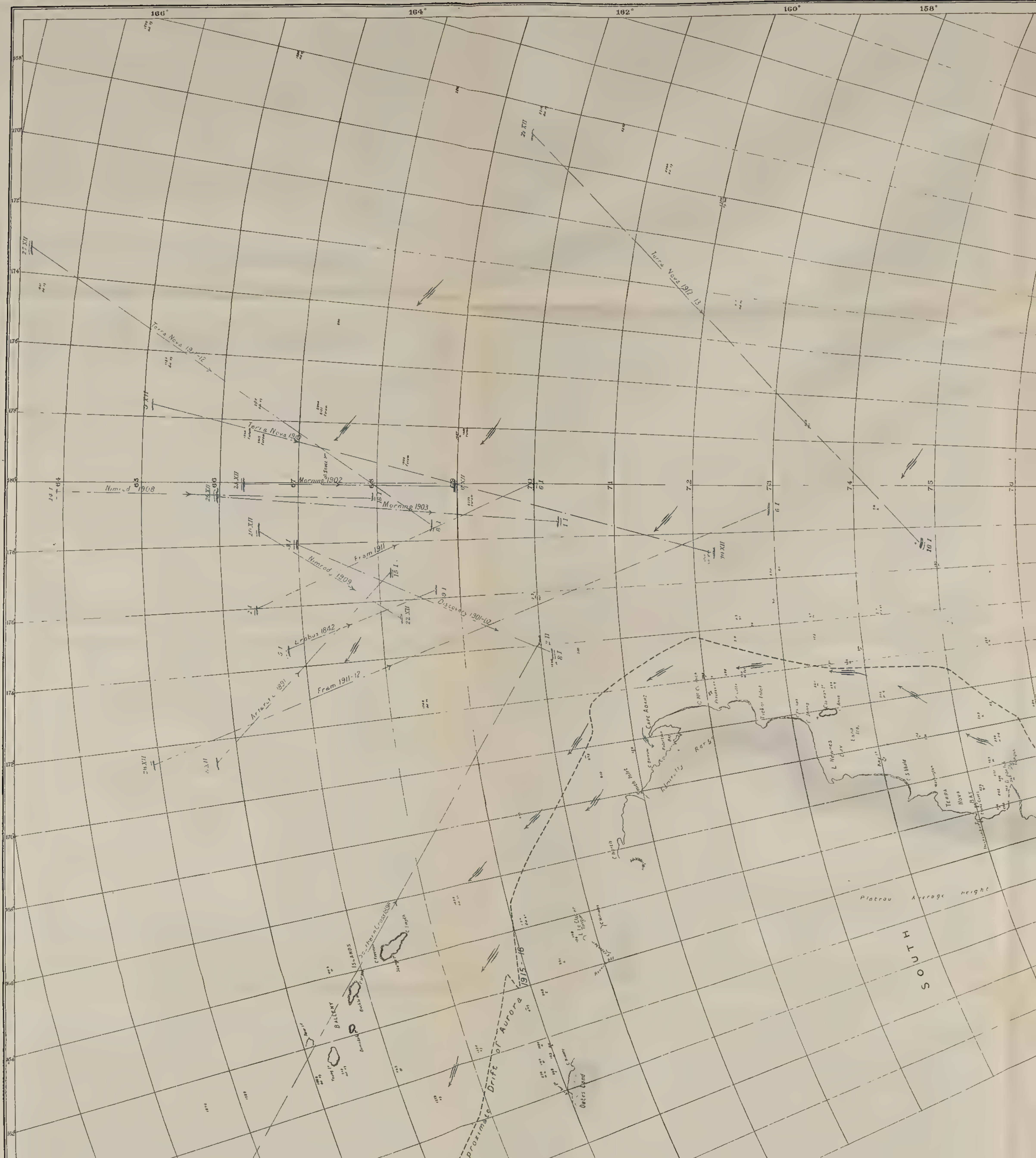
Statute Miles

Kilometres.

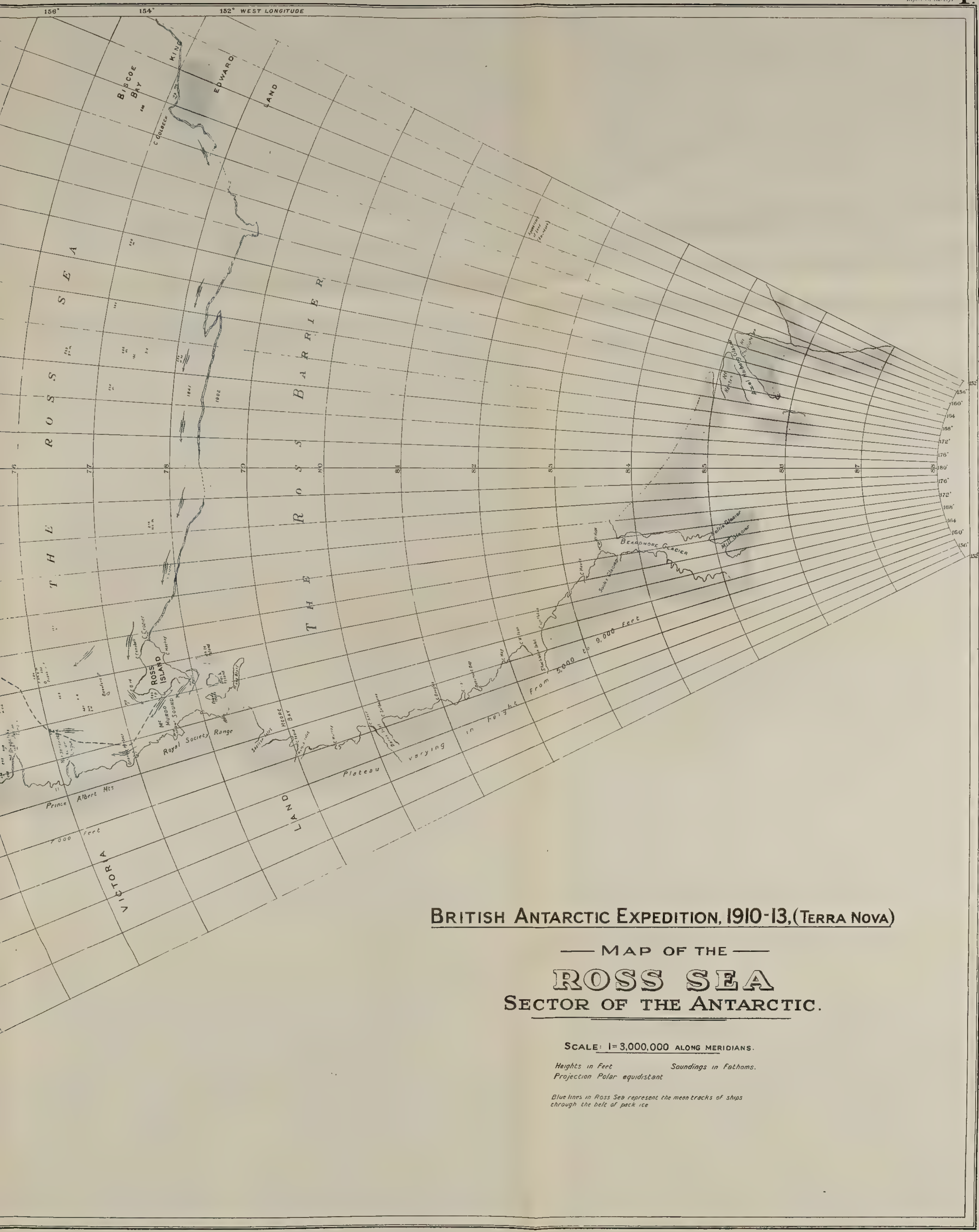
Heights in Feet. Contours at 1000 feet interval.
Arrows along the the route represent the direction and comparative dominance of sastrugi
Projection: Polar Equidistant.


THE GREAT ICE BARRIER
CAPE CROZIER TO C
S.Y. TERRA NOVA, (BRIT. ANTA
Scale:— 1,1000,
Miles 20 18 16 14 12 10 8 6 4 2 0 20
Statute Miles
Kilometres 20 18 16 14 12 10 8 6 4 2 0 20
Kilometres.
Heights in Fe
Soundings in Fa
Projection – Conical, with
JUNCTION OF BARRIER WITH ROSS Iᴰ.
Heights in Feet. Soundings in Fathoms
Scale, 1/50,000.
Statute Miles
Kilometres
ROSS SEA
ROSS BARRIER
Adelie Penguin Rookery
Beach
Cliffs 200' to 400' high
Emperor Penguin Rookery
Cape Crozier
The Knoll
1200
1911
1903
70ft.
Pressure Ridges
77° 30'
Terraced Moraine
No Single Tide Crack
N
THE ROSS
THE ROSS
Cape Crozier
3/4 kn
3 kn
[1841]
[1911]
[1902]
Discovery Inlet
Barrier face very clean cut no signs of weathering
Barrier face uneven considerable overhang in places. Caverns and water-worn at foot
Considerably overhung Barrier Face clean
Face slightly weathered
Much weathered
460
455
410
354
350
312
308
318
316
325
260
275
231
280
283
250
167°
168°
169°
170°
171°
172°
173° E. of Greenwich
174°
175°
176°
177°
178°
179°
180°
77°
78°
78°30'
79°


ER & KING EDWARD LAND.
TO CAPE COLBECK,
ANTARCTIC EXPEDN. 1910-13.)
1000,000.
20 40 60 Miles
e Miles
40 60 80 Kilometres
metres.
s in Feet.
s in Fathoms.
cal, with standard 78°.
170° 169° 168° 167° 166° 165° 164° 163° 162° 161° 160° 159° 158° 157° 156° 155° 154° 153°
170° 169° 168° 167° 166° 165° 164° 163° 162° 161° 160° 159° 158° 157° 156° 155° 154° 153° 152° 151° 150° 149° 148° 147°
76° 76°30' 77° 77°30' 78° 78°30' 79°
S E A
B A R R I E R
BISCOE BAY
Heavy Pack-ice with many Bergs 1902.
Heavy Pack-ice with many Bergs and ice islands
AVERY ICE ISLAND
Feb 1st 1902
Fast Sea-ice decayed
Point
Cape Colbeck
Low Cliff
Large Caverns in Cliff
low undulating slopes up to 1000 feet with some crevasses
Much weatherworn Large Variations in Height
2 kn.
Much crevassed
Patches of Bare Rock
Alexandra Mts 2000 to 3000 feet.
KING EDWARD LAND
Clean Face
Clean face no overhang Remarkably uniform height
Much crevassed at entrance to bay
Bay of Whales
"Framheim"
1100
Approximate route 1911. (Prestrud)
Face of Barrier 1910-13, S.Y Terra Nova (Brit Antarctic Expn)
Face of Barrier. 1902. "Discovery" Survey
Face of Barrier, 1841, "Erebus" Survey


166°
164°
162°
160°
158°
Terra Nova 1911-12
Terra Nova 1910
Terra Nova 1912-13
Nimrod 1908
Morning 1902
Morning 1903
Fram 1911
Nimrod 1909
Discovery 1901-02
Erebus 1842
Fram 1911-12
Antarctic 1891
Southern Cross 1899
Approximate Drift of Aurora 1915-16
BALLENY ISLANDS
C. Smyth
Oates Land
Mawson 1912
CAPE ADARE
Robertson Bay
Admiralty Range
Smith Inlet
C. Barrow
Tucker Inlet
L. Newnes
Land Ice
C. Sibbald
TERRA NOVA BAY
Tongue
Plateau Average height
SOUTH
158°
156°
154°
132° EAST LONGITUDE

Report on Surveys I.



BRITISH ANTARCTIC EXPEDITION, 1910-13, (TERRA NOVA)

— MAP OF THE —

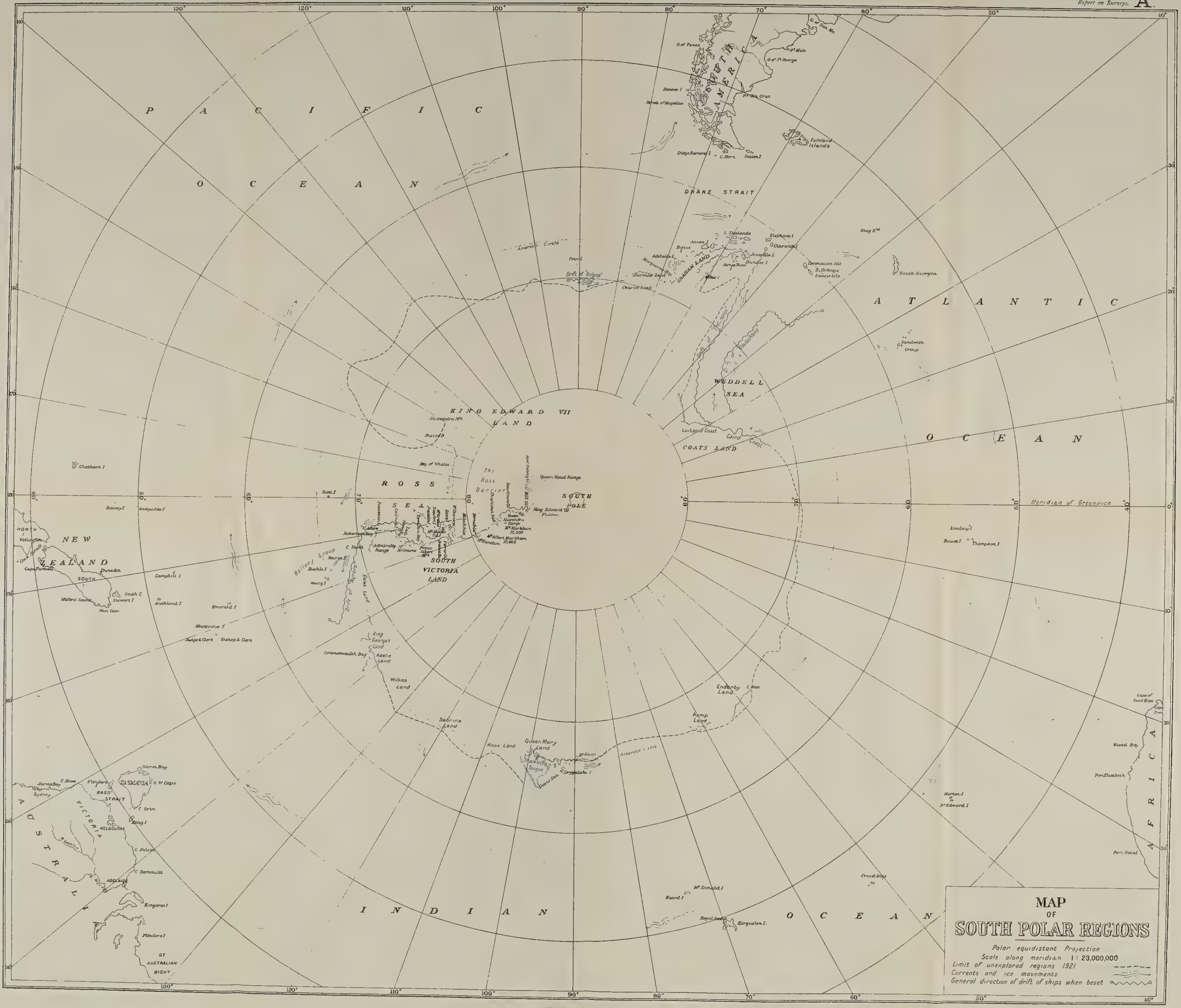
ROSS SEA

SECTOR OF THE ANTARCTIC.

SCALE: 1=3,000,000 ALONG MERIDIANS.

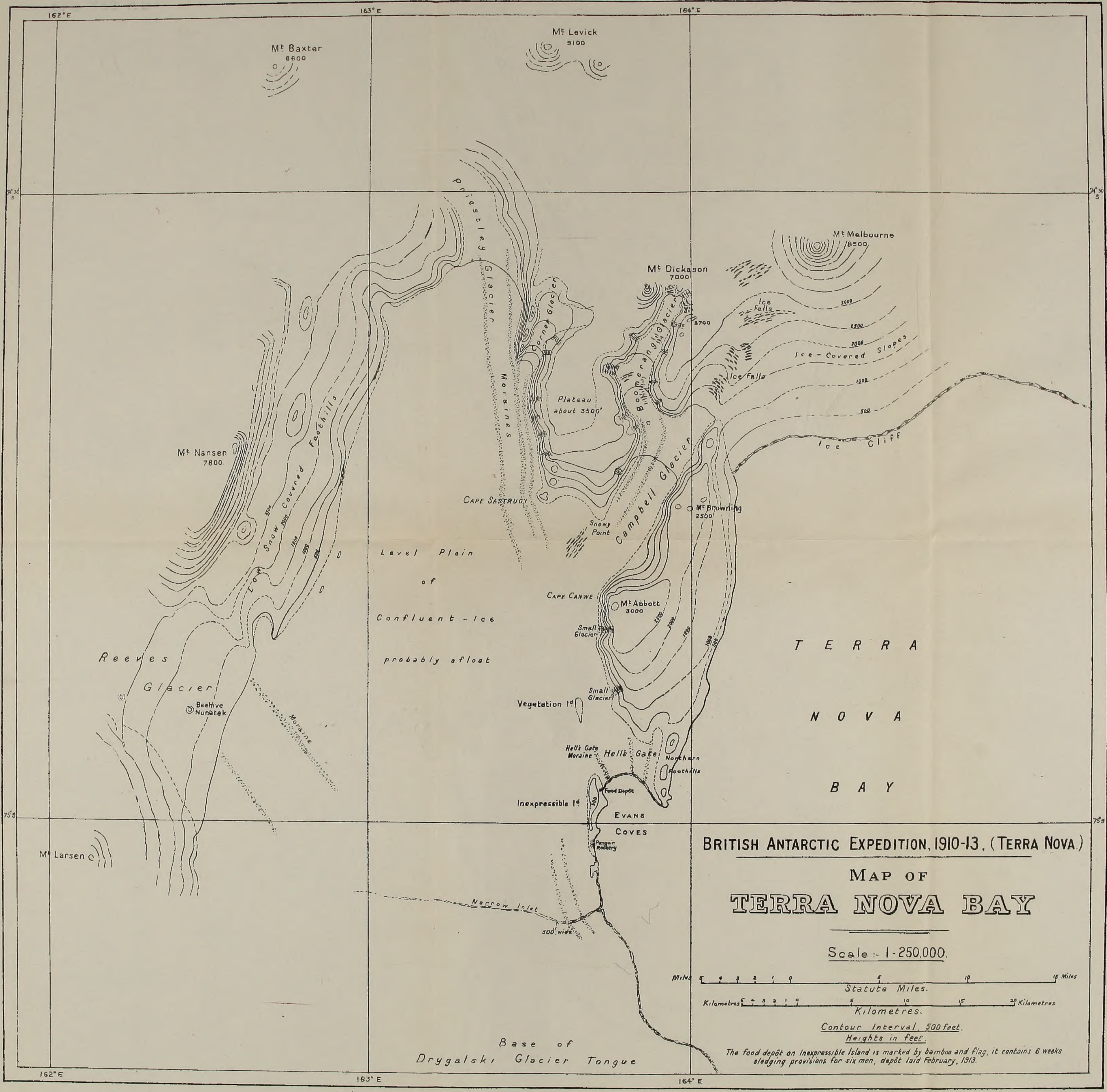
Heights in Feet *Soundings in Fathoms.*
Projection Polar equidistant

Blue lines in Ross Sea represent the mean tracks of ships through the belt of pack ice



MAP
OF
SOUTH POLAR REGIONS

Polar equidistant Projection
Scale along meridian 1 : 23,000,000
Limit of unexplored regions 1921
Currents and ice movements
General direction of drift of ships when beset



BRITISH ANTARCTIC EXPEDITION, 1910-13, (TERRA NOVA.)

MAP OF

TERRA NOVA BAY

Scale :- 1-250,000.

Statute Miles.

Kilometres.

Contour Interval, 500 feet.

Heights in feet.

The food depôt on Inexpressible Island is marked by bamboo and flag, it contains 6 weeks sledging provisions for six men, depôt laid February, 1913.

HARRISON & SONS, LTD., LITH. ST MARTIN'S LANE, W.C.2.